Weatherwise

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FEBRUARY 1958

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

AMS Elections and Awards

THE election of a new president, vice-president, and five councilors was announced at the 38th Annual Business Meeting on 29 January 1958.

Dr. Sverre Petterssen, Professor of Meteorology at the University of Chicago, was elected to serve a two-year term as president, succeeding Dr. Robert D. Fletcher. Dr. Petterssen, a native of Norway, is well-known to international meteorology through his service as advisor to many national weather services. His many publications have greatly influenced meteorological study and thinking.

Mr. Henry Harrison, Director of Meteorology for United Airlines, was elected as vice-president. A veteran of the Byrd Antarctic Expedition, Mr. Harrison has held many positions with United Airlines and has recently pioneered the use of weather radar on commercial aircraft.

Dr. Thomas Malone, Director of Research, The Travelers Insurance Company, will serve another term as secretary, as will Mr. Henry Ward of Eaton and Howard, Boston, as treasurer.

The new councilors to serve three-year terms are:

James M. Austin, Massachusetts Institute of Technology
Robert G. Beebe, U. S. Weather Bureau, Kansas City
R. Corday Counts, U. S. Weather Bureau, San Francisco
Joe R. Fulks, U. S. Weather Bureau, Chicago
Albert K. Showalter, U. S. Weather Bureau, Washington

At the annual dinner the Society's Award for Outstanding Services was presented to Prof. Henry G. Houghton of M.I.T. for "his important contributions to the growth of the American Meteorological Society through his guidance as president, as secretary, and his unfailing service in council and committee work."

Vol. 11, No. 1 February, 1958

CONTENTS

Progress During 1957 in American Meteorology
— Robert D. Fletcher 3

The Circulation and Weather of 1957
— William H. Klein 7

Tornadoes During 1957
— Robert G. Beebe 13

The 1957 Hurricane Season
— Walter R. Davis 17

Some Noteworthy Snows of 1956–57
— David M. Ludlum 20

Drought in 1957
— Wayne C. Palmer 23

Weatherwatch 26

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Dr. Robert Fletcher, president of the AMS, receives bouquet from the Japanese Meteorological Society, presented by Miss Otani, Japan's 1958 Miss Universe Contestant.

Progress During 1957 in American Meteorology

ROBERT D. FLETCHER, *President, American Meteorological Society*

OUTSTANDING among events in the weather field during 1957 was the first six months' activity of the International Geophysical Year. For the first time in history, a thorough coverage of meteorological conditions over the Antarctic Continent has been effected. This accomplishment, together with Soviet successes with earth satellites, has whetted the interest of the scientific mind—as never before—in the interplay of geophysical phenomena over the world as a whole and to the edge of outer space. 1957 was truly the year in which our science and profession came point blank to the realization that we must expand our horizons.

Meantime, the growing American Meteorological Society has been taking action to strengthen the position of our field among the many professional and scientific groups of this country. These actions have resulted from careful thinking and downright hard work on the part of our committees, local branches, and Executive Office. In the following paragraphs are items selected to illustrate our progress in specific areas during 1957.

EQUIPMENT

Research and development in meteorological instrumentation proceeded in 1957 with a heavy accent on automation. In an effort to meet the rapidly increasing needs for greater speed and accuracy in provision of weather service, the Geophysical Research Directorate of the Air Research and Development Command started work on a Weather System (Project 433L) designed to tie together the observational, data-processing, communications, forecasting, and data-presentation phases of our work into one package. High-speed communications equipment and electronic computers are the basic ingredients of this program, currently being studied by all pertinent governmental agencies for its feasibility as the general United States system of the 1960's.

The first phase of the "approach-visibility" installation at the Newark Airport in New Jersey was completed. This project, aiming at an accurate and efficient system for aircraft landings under instrument conditions, uses the rotating-beam ceilometer, transmissometer, and illuminometer. Data are fed into an automatic computer, now under test, which turns out two operational parameters called Approach Light Contact Height and the Runway Visual Range. Work has begun on the next phase in which the system will be tested at Andrews Air Force Base, Maryland, for feasibility of use with jet aircraft.

Final testing of the GMD-2 upper-air sounding equipment was started in 1957. This instrumentation, being developed by the Signal Corps, measures the slant range to a balloon-borne target to provide wind information far more accurately than is now operationally available. It also automatically computes the standard meteorological elements of pressure height, altitude, temperature, and humidity. Plans were laid to extend its use

to rocketsondes in order that data can be secured for heights above the ceiling of the present balloons. In June the Navy Transosonde Program became operational to make available 300-mb data secured by balloons floating over the Pacific Ocean. The National Advisory Committee for Aeronautics, in cooperation with the Air Weather Service, collected data up to nearly 55,000 feet with a specially instrumented research aircraft, the Lockheed U-2, for study of high-level turbulence and local variations of temperature and humidity.

During the year the Weather Bureau added locations at which automatic weather stations sensed and transmitted hourly observations. The Air Weather Service, meanwhile, expanded its test "Weathervision" program to include six stations where weather information is sent by television from a central forecast office to various military customers in the vicinity.

Special Meteorological Programs

Of all the programs conducted during the year the spotlight was on the intensive efforts of the IGY. A major achievement was the establishment in the Antarctic of seven well-equipped stations on the continent. One of these stations is located precisely at the geographic South Pole, another is operating as a weather central to provide detailed forecasts as needed. The Amundson-Scott South Pole Station has already recorded a new world-record minimum temperature of $-102.1°F$, and the long-range prediction has been made that a low of $-112°F$ will be observed.

As part of the IGY program, the U. S. Weather Bureau, in cooperation with services of Canada and several South American governments, is operating a line of stations reaching from pole to pole along approximately the meridian of 80° West. The Air Force has conducted several weather-reconnaissance flights, one of them between Puerto Rico and the coast of Africa, to collect special weather data for inclusion in the IGY data files.

The National Hurricane Research Project, conducted by the Weather Bureau, completed the part of its program originally designed to collect hurricane data with specially-instrumented Air Force reconnaissance aircraft. Because the number of hurricanes in range of West Palm Beach, the project's base of operations, was abnormally small, arrangements were made for an additional year of employment of the research aircraft. The Project's aircraft (two B-50's and one B-47) made several flights to collect data in easterly waves for use in studying the hurricane-genesis problem. Sixty-five cooperative hurricane-observation stations were installed in a special network along the coasts of the Gulf of Mexico and Atlantic Ocean.

The Meteorological Committee of the National Academy of Sciences conducted extensive investigations of deficiencies in the meteorological science during 1957 and has sought the advice of the American Meteorological Society along with other organizations. The Committee's main concerns are to bring additional scientific talent into our ranks and to increase research in basic meteorological problems. Its completed report will be presented early in 1958.

The Advisory Committee on Weather Control completed its activity and was dissolved at the end of 1957 when its final report was presented to President Eisenhower. Legislation was introduced to extend the government's interest in weather modification by enabling the National Science Foundation to support financially and to sponsor research in weather modifications. The findings of the Advisory Committee have been of great assistance to the American Meteorological Society's Committee on Weather Modification in the preparation of an AMS Statement on such matters.

Weather Forecasting

The trend in the weather-prediction activities of our civilian and military weather services during 1957 was toward systematization and objectivity. Factors motivating this trend were the need to utilize competent personnel efficiently in the face of manpower shortages and increasing operational requirements, and the need to integrate new electronic-computer capabilities efficiently into the weather-forecasting system. Action was begun to establish terminal-forecasting centrals at several locations in the United States.

Significant progress continued in the field of numerical prediction. Advances have come about both through improvement in prediction models and through the expansion of physical facilities. The computational

capability of the Joint Numerical Prediction Unit at Suitland was increased eightfold by replacement of the IBM 701 electronic computer by the IBM 704. This expanded capability played a large part in the improvement of the prediction model. After installation of the 704, the area covered by the one-level barotropic model was expanded to encompass the entire Northern Hemisphere down to about 15°N latitude. The impact of this areal expansion has been felt in two ways: first, in the extension of forecast usability through the expansion of the area covered by the predictions; and secondly, by improvement in the over-all forecast quality by fixing boundary locations in areas least likely to distort the internal forecasted values. Much of the year's actual advances in the development have resulted from better understanding and improved handling of errors associated with the geostrophic assumption. During the year, problems pertaining to the handling of this assumption have been encountered, worked upon, and solved. An improved ageostrophic calculation method is an integral part of the new expanded hemispheric prognoses and has given excellent results. At the beginning of 1957, automatic data processing and a multi-level (baroclinic) model were operating with the 701. The acquisition of the IBM 704 opened up new vistas for both. To take advantage of the new computational capability, it was necessary to discontinue temporarily these two programs to permit the development of a more realistic multi-level model and a more versatile automatic data-processing program. At the year's end, a new improved automatic data-processing program was ready for use—one which will require "no hands" from the teletype tape to the finished forecast. Soon to follow will be the new, much improved, multi-level-model program which will provide forecasts for any pressure surface from 1,000 to 300 mb over most of the Northern Hemisphere for any period up to 72 hours. Similar forecasts for vertical motion, mean vertical stability, mean temperature, and state-of-the-sea (wave heights) will also be available. The tangible results of the year's progress in numerical prediction will become evident during 1958 with the anticipated large upward trend in the substitution of machine-prepared prognoses for those currently produced subjectively.

In addition to developments in the solution of the more immediate operational problems, progress has been made in research efforts to include the moisture variability in the numerical models, to develop numerical methods for forecasting hydrometeors, to develop numerical techniques for longer-period forecasts, and to study general atmospheric-circulation problems.

In the field of statistical meteorology, early attempts at prognosis through machine-developed statistical techniques have shown considerable promise. To improve local forecasting by objective techniques, machine programs applying sophisticated statistical methods have been completed and are now being used to compute local forecasting regression-equation coefficients for individual stations.

An anticipated consequence of the development of the numerical-prognosis program is the crowding of the communications system if we attempt to transmit all the usable information the computers will produce. It poses a real dilemma for a teletype system that prints only one five-digit number per second to try to keep up with a machine that can add over 40,000 ten-digit numbers in the same time. Fortunately, marked developments in communications systems promise to alleviate this problem.

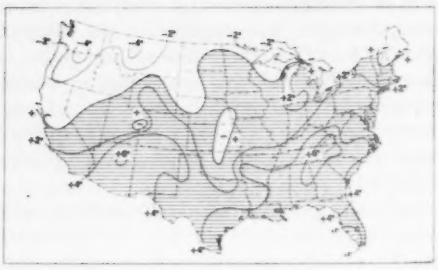
Under a joint fur.ding effort by the Air Force, Weather Bureau, and Navy, the Bureau of Standards developed FOSDIC for the three services to speed up climatological data processing. FOSDIC stands for Film Optical Sensing Device for Input to Computer. The machine is designed to microfilm cards, punched for desired data, at the rate of 4,300 observations per minute. When observations meeting specific criteria are located, the machine stops the film, re-reads the micro-frame, and transfers the frame data out to a card-punching machine.

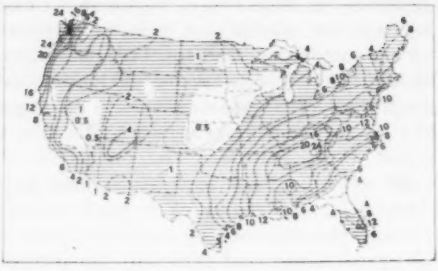
Emphasis on jet- and turbine-power-aircraft operations has caused a shift to a 250-mb chart as the basic weather chart for some forecast centers. The National Weather Analysis Center has increased the number of high-level analyses which are transmitted via facsimile, and their schedule now includes

(*Continued on page 30*)

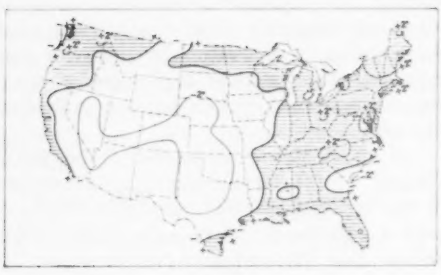
THE WEATHER BY SEASONS 1957

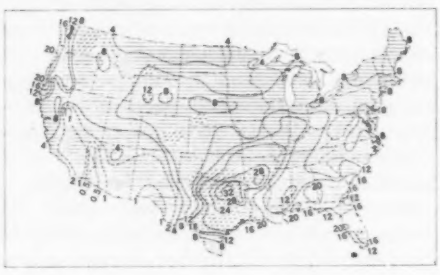
WINTER (DECEMBER–FEBRUARY) 1956–1957



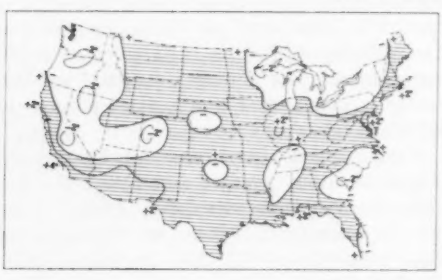


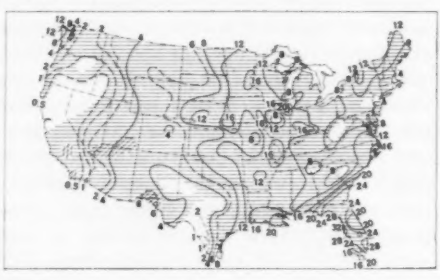
SPRING (MARCH–MAY) 1957



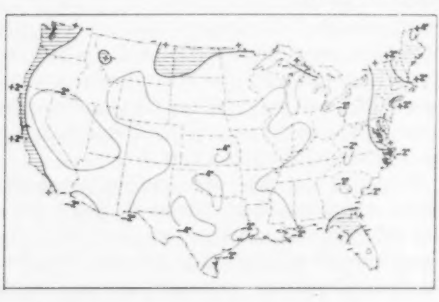


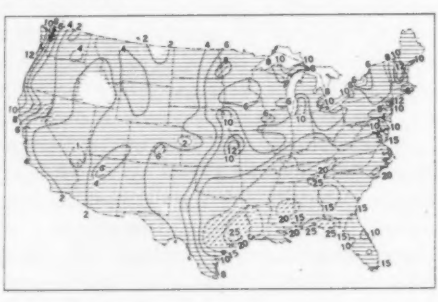
SUMMER (JUNE–AUGUST) 1957





FALL (SEPTEMBER–NOVEMBER) 1957





Charts show the departure of the temperature from normal in degrees Fahrenheit by seasons 1957. USWB charts.

Charts show the total precipitation in inches by seasons 1957. USWB charts.

The Circulation and Weather of 1957*

WILLIAM H. KLEIN, *Extended Forecast Section, U. S. Weather Bureau*

THE YEAR AS A WHOLE

THE outstanding characteristic of the general circulation during the year 1957 was the dominance of low index in the western half of the Northern Hemisphere. Sea level values of the zonal index, which expresses the average strength of the prevailing westerly winds between 35° and 55°N., are plotted in figure 1 for overlapping 30-day mean periods computed twice-monthly. Comparison with the long-period normal (dashed curve) shows that the index was below normal each period from January to November 1957, except for a brief interlude during April. The lowest index and greatest departure from normal were reached during the period from mid-September to mid-October. Subsequently the strength of the mid-latitude west winds increased rapidly, with the index finally climbing to above-normal value during the period from mid-November to mid-December.

Low index circulations are frequently accompanied by extremes of weather and unusual storminess in temperate regions. It is not too surprising then, that the weather of 1947 in the United States was highlighted by a record number of tornadoes, disastrous floods in central sections, and severe drought in the East. A reflection of the anomalous nature of the circulation for the year is revealed by the fact that such widely separated cities as Dallas, Texas; Denver, Colorado; Billings, Montana; and Tampa, Florida, each recorded more precipitation during the first ten months of 1957 than had been observed at these stations during any previous calendar year of record. The 1957 annual total of 77 inches precipitation at Memphis, Tennessee, was more than 27 inches greater than normal and broke a record dating back to 1872. In sharp contrast, 10-month deficiencies of precipitation were the greatest of record at several cities in the Northeast. The regional circulation patterns associated with these abnormalities of weather will now be discussed on a monthly and seasonal basis.

* This paper is based on the series of articles on the weather and circulation of each month appearing regularly in the *Monthly Weather Review*.

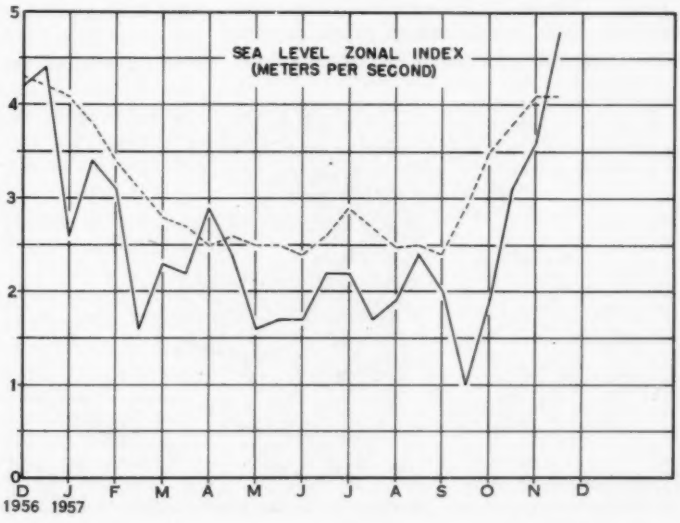


FIG. 1. Time variation of west wind component at sea level averaged over the Western Hemisphere in the latitude belt 35° to 55°N. Solid lines connect observed 30-day mean values computed twice-monthly from December 1956 to December 1957, while dashed lines show the corresponding normal. From January to November 1957, the index was below normal every period except one.

Winter

The mean circulation at sea level during January 1957, shown in figure 2, was dominated by two great centers of action. The first was the Icelandic Low, whose central pressure intensity averaged 983 mb, 11 mb deeper than normal. The second was an anticyclone in the Yukon Territory of northwest Canada, where pressure averaged 1,030 mb, 16 mb above normal. Between these two features stronger than normal northwesterly flow covered practically all of Canada, both at sea level and aloft. This flow carried large quantities of abnormally cold polar continental air masses into the United States. Successive cold outbreaks were associated with the passage of numerous migratory anticyclones, originating as breakoffs from the parent high in the Yukon and moving southeastward into the United States along two well-defined tracks, shown by the arrows in figure 2. As a result temperatures for the month averaged below normal in all parts of the country except the Gulf and Southern Rocky Mountain States, with greatest departures (−14° F.) in Montana. Several new absolute lows were recorded on the 15th and 18th in the Northeast (−34° Birch Hill Dam, Mass.—new state minimum) and on the 26th and 27th in the Northwest (−25° F. at Burns, Oregon).

In contrast to January, February 1957 was an unusually warm month in the United States. Only in the extreme Northwest were monthly mean temperatures below normal, and these only slightly. The change from January was very marked, and in no area did it cool by as much as one temperature class (out of five). In fact, temperatures over a broad belt extending from coast to coast across the central United States warmed by two classes or more, with four-class changes (from much below to much above normal) observed in parts of New England and the Central Plains. The corresponding change in circulation pattern is illustrated in figure 3. The following four factors were responsible for the warming: 1) weakening and retrogression of the ridge in the Gulf of Alaska, so that air flow entering western North America was mainly maritime rather than continental in oirgin, 2) increase in 700-mb height values over the whole of the United States except the Gulf Coast, 3) development of confluence and a strong westerly jet across the northern tier of States, thereby containing cold polar air masses in Canada, and 4) increase in easterly flow carrying mild Atlantic air into the East.

Spring

The weather in the United States during the spring of 1957 was severe in many areas. The prolonged drought of 1952–56 in southern and central parts of the Great Plains was broken by blizzards and heavy rains during both March and April. Intensification of the heavy precipitation during May produced disastrous floods in this region. At the same time tornado activity, which had been frequent in April, reached peak intensity and made May 1957 the worst tornado month ever experienced in the United States.

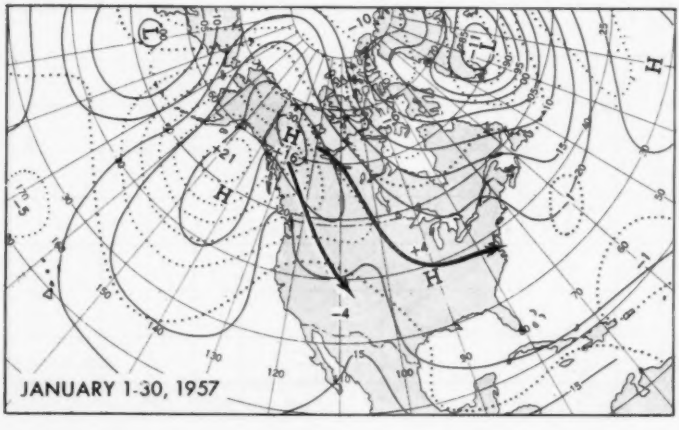


Fig. 2. Mean sea level chart for January 1957. Solid lines are isobars labeled in mb (last two digits only) and drawn at 5-mb intervals. Departures from normal of sea level pressure at 4-mb intervals are shown by dotted lines with centers labeled in millibars. Solid arrow-head curves represent principal tracks of migratory anticyclones responsible for frequent outbreaks of cold polar air in the United States.

The principal circulation feature responsible for this spring's stormy weather in the central United States was a deep mean trough which formed in the Mississippi Valley and Southern Plains during March, covered the Northern Plains and Southern Plateau in April, and retrograded to the West Coast during May. At the same time a mean ridge which developed along the East Coast in March remained quasi-stationary and intensified during April and May. Both of these features were well marked at all levels of the atmosphere from sea level up to 200 mb (about 40,000 ft). The circulation between them carried a strong current of extremely moist air from the Gulf of Mexico into central and eastern parts of the United States at low levels. One index of this moist southeasterly flow is the fact that the mean sea level pressure gradient between New York City and Brownsville, Texas, during April and May 1957 was 7 mb greater than normal. Another indication was obtained by measuring the sea level pressure difference between New Orleans, Louisiana, and Laredo, Texas, on each day of April and May. This index was considerably greater in 1957 than in any of the previous 5 years of record.

One of the primary mechanisms for releasing the Gulf moisture in the form of precipitation was forced ascent of tropical air in convergence zones in the vicinity of quasi-stationary frontal surfaces. The number of days that fronts of any type appeared on the Daily Weather Map (within 500-mile squares) during April and May is shown in figure 4. Especially noteworthy in the elongated 30 isoline in the central United States, indicating that fronts were present about half the time. These fronts were generally oriented from northeast to southwest, extending from the Ohio Valley through central Texas. Some of the heaviest rains fell in connection with minor perturbations within this mean frontal zone.

To the north and west of the frontal zone, cool polar air masses predominated. Some of this polar air filtered into the northern part of the United States from the circula-

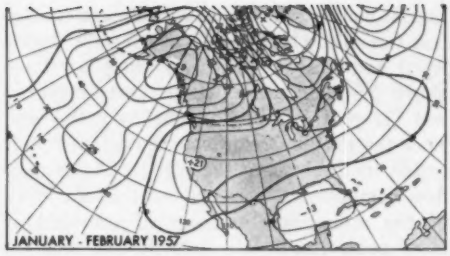


FIG. 3. Mean 700-mb height departures from normal for February 1957 minus those for January 1957. The lines of equal anomalous height change are drawn for every 100 ft with the zero line heavier and centers labeled in tens of feet. Increased flow of maritime air from both the Atlantic and the Pacific produced widespread warming in the United States.

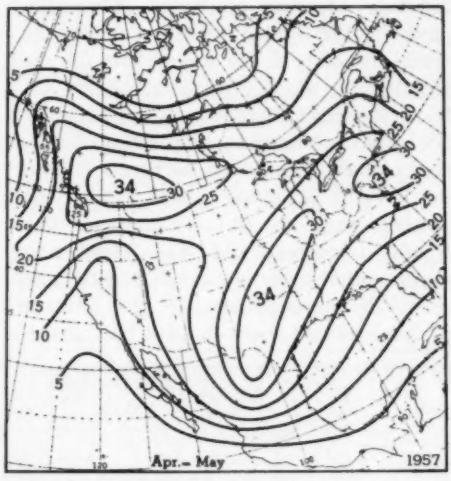


FIG. 4. Number of days in April and May 1957 with fronts of any type within unit squares (with sides approximately 500 miles). All frontal positions taken from Daily Weather Map, 1330 EST. The elongated 30 isoline in the south-central United States delineates the area of the worst floods and tornadoes.

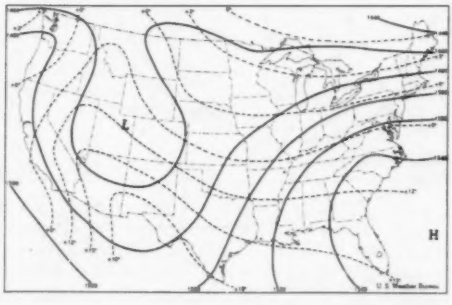


FIG. 5. Mean 850-mb chart (about 5,000 ft) for April and May 1957. The contours (solid) are labeled in geopotential meters; the isotherms (dashed) are in degrees C. Their intersections denote areas of marked warm and cold advection.

tion around a strong continental high in central Canada, where sea level pressure during April and May averaged as much as 6 mb above normal. More important, however, was the polar air which came from the west since the Pacific Ocean is an important source region for cool air in the spring. Anomalous flow components from the west at all levels of the atmosphere transported considerably more polar Pacific air than normal into the southwestern United States, where spring temperatures averaged below normal. On the other hand, abnormal warmth prevailed in the eastern half of the United States because of the northward transport of warmer than normal tropical air masses.

Cold-air advection in the Southwest and warm-air advection in central and southern parts of the United States are well illustrated by figure 5, the mean chart for April and May at the 850 mb level (about 5,000 ft). Of special importance is the large number of boxes formed by intersections between the contours (solid) and isotherms (dashed) in the area of severe floods (from Texas northeastward to Illinois) and maximum frontal frequency (fig. 4). Here strong south-southwesterly geostrophic winds were practically perpendicular to the isotherms, so that indicated warm-air advection appeared to be greater than anywhere else on the map. Such a situation is generally associated with upward motion and precipitation on a synoptic basis. Furthermore, apparent warm advection as defined by the cross pattern of isotherms and contours near the 850 mb level is related to the frequency of thunderstorms and tornadoes in the central United States. This is significant because some of the flood-producing rain fell as heavy showers during severe thunderstorms and tornadoes.

Summer

In many respects the weather and circulation regime of June was a continuation of that which had prevailed throughout the spring season. A stronger than normal ridge remained quasi-stationary along the East Coast, while a deep mean trough was located in the Great Plains. As a result tornadoes, heavy rains, and floods in central portions of the United States again made newspaper headlines, but drought intensified along the East Coast. Surface temperatures remained above normal in the eastern half of the country and along the West Coast, while below normal temperatures dominated central sections.

Although many features of June's weather and circulation were quite persistent from the preceding month and season, nevertheless, there were some large changes. One of

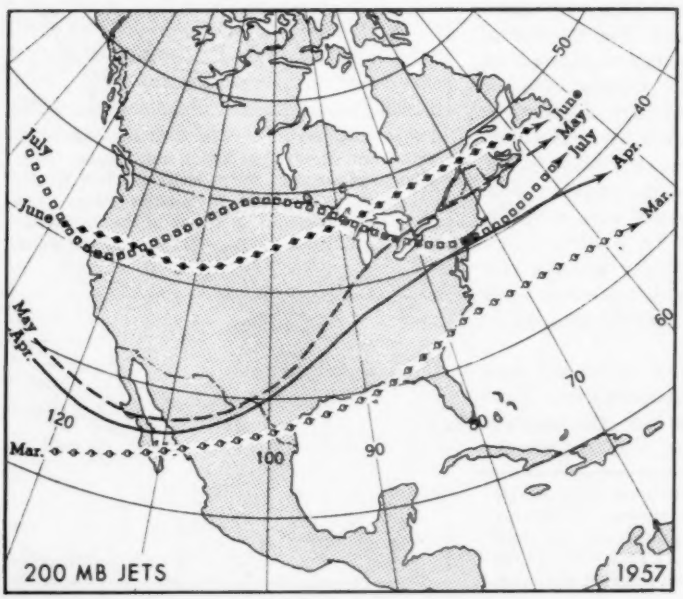


Fig. 6. Location of principal axis of mean jet stream at 200 mb level (about 40,000 ft) as obtained from a series of monthly mean charts from March to July 1957. Note marked northward shift of the jet in the West from spring to summer months and development of cyclonic curvature in East during July.

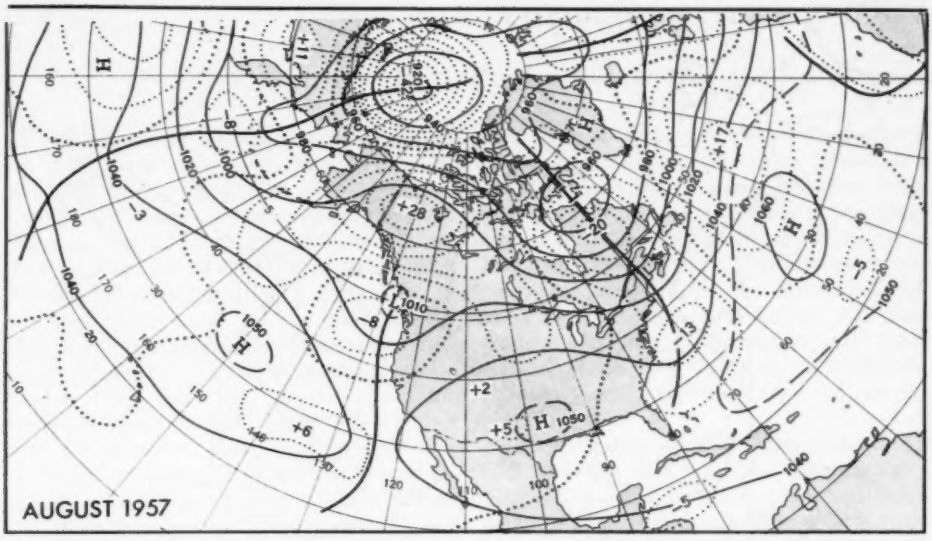


FIG. 7. Mean 700 mb chart for August 1957. The contours (solid) are labeled in tens of feet, with intermediate contours dashed. The lines of equal departure from normal 700 mb height (dotted) are drawn for every 50 ft with the zero line heavier. Anomaly centers are labeled in tens of feet. Important features include warm High over Texas and deeper than normal mean troughs (delineated by heavy vertical lines) off east and west coasts of United States.

the most striking was the warming which occurred in the Southwest, where many stations reported a four-class change in temperature, from much below normal during May to much above normal in June. This warm-

(*Continued on page 32*)

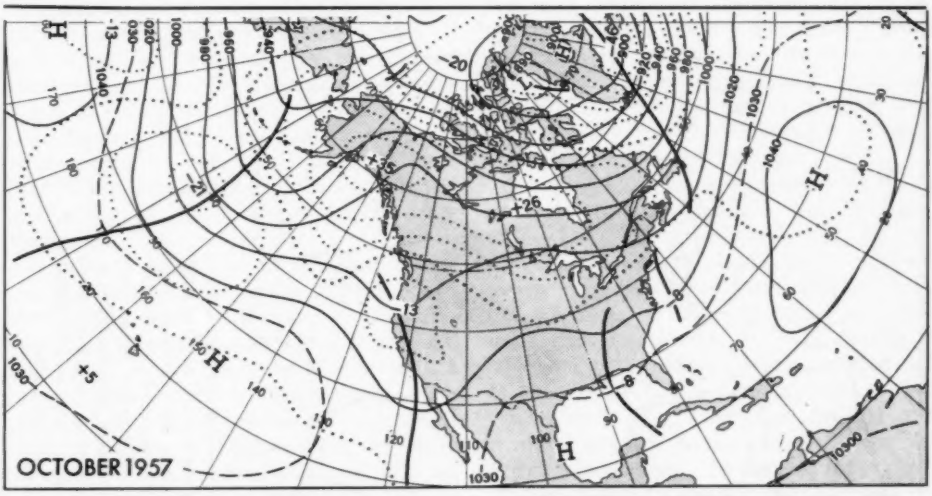
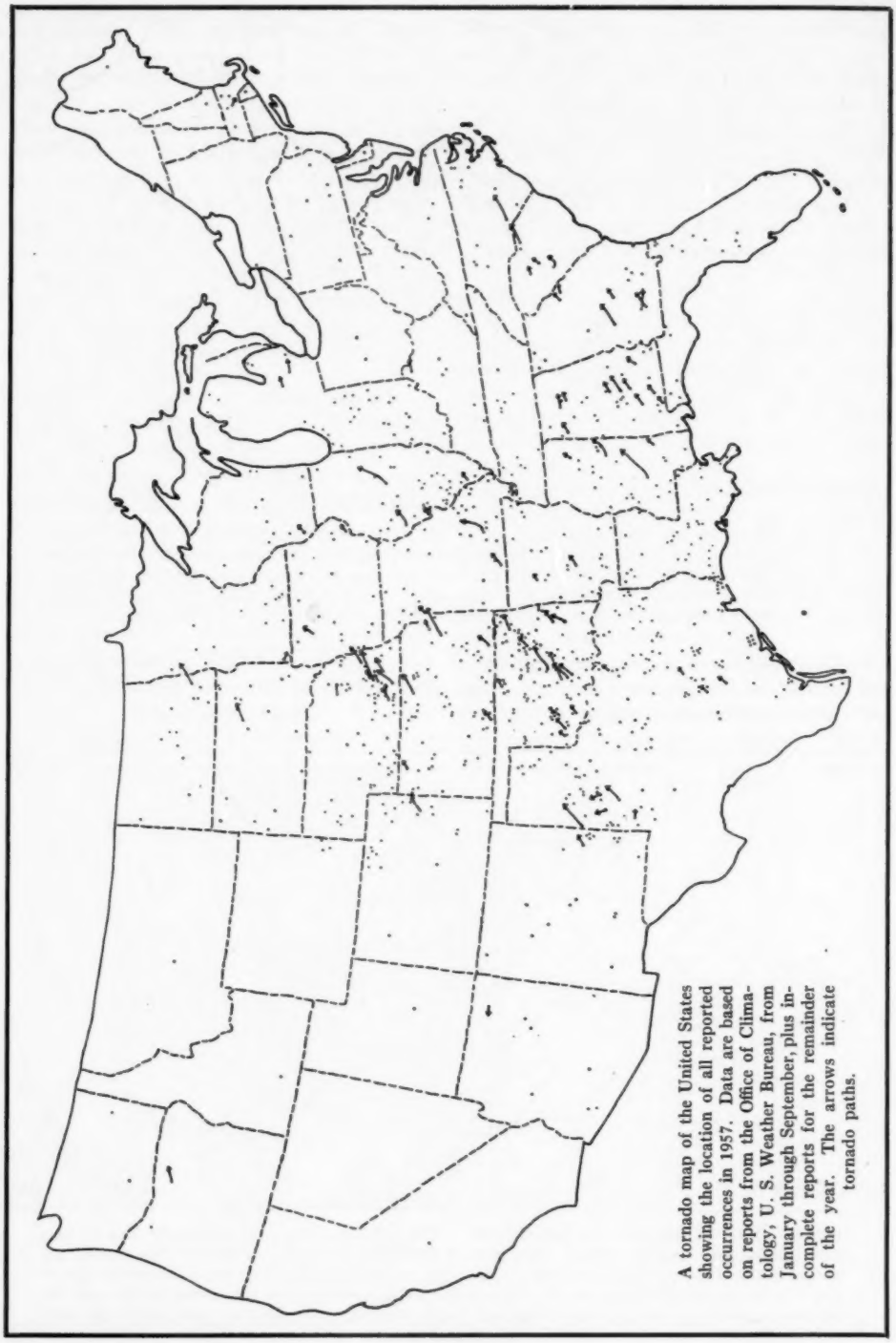


FIG. 8. Mean 700 mb chart for October 1957. The contours (solid) are labeled in tens of feet, with intermediate contours dashed. The lines of equal 700 mb height departure from normal are dotted and drawn for every 50 ft with the zero line heavier and anomaly centers labeled in tens of feet. Note the diffluent nature of the westerly current emanating from the central Pacific and the blocking character of the anomaly field over North America, with resultant weak westerlies over the United States.



A tornado map of the United States showing the location of all reported occurrences in 1957. Data are based on reports from the Office of Climatology, U. S. Weather Bureau, from January through September, plus incomplete reports for the remainder of the year. The arrows indicate tornado paths.

Tornadoes During 1957

R. G. BEEBE, *U. S. Weather Bureau, Kansas City, Missouri*

THE number of tornadoes reported during 1957 again set a new record, exceeding the 1955 total of 874, with over 1,600 tornadoes and funnel clouds reported to the Weather Bureau's Office of Climatology. The locations of the 961 tornadoes which actually touched the ground are shown on the map. One reason for the great number this year, was undoubtedly the increased incidence of convective conditions and thunderstorms which form the natural setting for tornado outbreaks. The unusually wet spring over the Southern Plains was indicative of the above normal thunderstorm activity. Of course, part of the increase is again due to the same factors that have prevailed since the initiation of tornado forecasts in 1952: the growth in population, the additional number of weather stations, improved communications, but, most of all, to a heightened interest in tornadoes.

Tornadoes were directly responsible for the loss of about 154 lives this past year. These deaths were caused by 14 different tornado situations, or only about one per cent of the total number of tornadoes. Looking back to a year before tornado forecasting began, a year which had a comparable loss of life, there were 140 deaths from 19 tornado situations in 1948, or 10 per cent of the 190 tornadoes reported. This suggests that many more reports of tornadoes causing no more than minor damage are now being received and account for much of the apparent large increase in tornado occurrences.

The most spectacular tornado outbreak of the year occurred during the afternoon and evening of 2 April. Altogether, 43 tornadoes and funnels were reported over Texas and Oklahoma, 16 persons were killed, and 226 persons were injured in this situation. The tornado that moved northward across the western portion of Dallas caused extensive damage and most of the deaths and injuries. However, the feature of the Dallas tornado that will be long remembered is the extensive amount of information that is available for tornado research. This tornado was photographed from before it first reached the ground until after it dissipated. From these photos it may be noted that the vortex formed as a broad funnel with a relatively low cloud base; later became more of a column as the cloud base lifted; and dissipated as it became a long, rope-like vortex. This life cycle was previously reported in the Scottsbluff tornado (1). Altogether, 450 black and white photos, 250 color transparencies, and 1,500 feet of movie film, taken by 125 different photographers, have been compiled for research.

An important part of these photographic records is the film taken by Maurice Levy, NBC News photographer, showing buildings exploding and debris moving in the tornado circulation. Prints were made from this film and the speeds of some 400 individual pieces of debris were measured. Surprisingly, no speed exceeded 125 mph and large pieces (20×12 feet) moved as fast as small pieces until thrown out of the circulation. An example of how the speed of movement of debris was calculated is shown in the two photos. In the first photo, the building has just been lifted off of the ground and is beginning to break apart. The second photo was taken 1.5 seconds after the first photo. Object No. 1 moved 60 feet, or 27 mph; object No. 2 moved 120 feet, or 54 mph; and object No. 3 moved 175 feet, or 81 mph during this 1.5 second interval.

Texas and Oklahoma were again hit by an extensive tornado outbreak on 15 May. From 1500 CST until midnight, 26 tornadoes and funnel clouds were reported, mostly over the Texas Panhandle and central Oklahoma. One of these tornadoes truck Silverton, Texas, at 2235, leveled a large well-built residential area, snuffed out 21 lives, and left 80 persons injured.

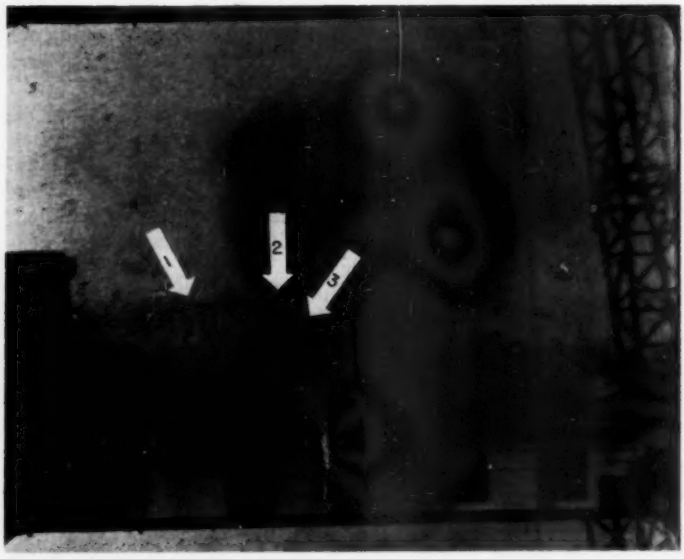
The week of 19–25 May brought the greatest number tornadoes ever recorded during a single week. In the area from Texas northward into Nebraska and eastward to Indiana, 237 tornadoes and funnel clouds were reported in seven days. These destructive storms killed 52 persons, injured over 300 others, and damaged millions of dollars worth

of property. During the evening of 19 May, several tornadoes struck in the Nebraska Panhandle. The following afternoon, a series of 50 tornadoes and funnels broke out over Nebraska, Kansas, and eastern Missouri, killing 33 persons. This storm setting continued eastward and, shortly after noon of the next day, 21 May, tornadoes began developing close to the Mississippi River from near Dubuque, Iowa, to Cairo, Illinois. Twenty-two tornadoes and funnel clouds were reported that afternoon and evening from the Mississippi eastward into northwest Indiana; 15 people were killed. On the following day, 22 May, tornadoes began forming around sunrise in central Oklahoma, and before midnight some 40 twisters and funnel clouds were observed in Texas, Oklahoma, Kansas, and Missouri. Conditions eased up somewhat on Thursday, 23 May, with only 13 observed, mostly in northeast Texas and the southern part of Arkansas. However, this was only a temporary lull, and even before noon of 24 May, activity commenced in the Texas Panhandle. By midafternoon, this area of tornadic conditions had moved into Oklahoma, and the total count reached 71 by the end of the day. The next two days were relatively quiet with 20 occurrences reported.

The outstanding tornado disaster of the year was the Kansas-Missouri tornado on 20 May (2). The path of this tornado was 71 miles long and for most of its length, was between 0.2 and 0.4 mile wide. It moved at about 40 miles per hour. In flying over this path on the morning after the disaster, it was observed that the track was continuous and damage was the most extensive that the tornado damage survey teams had ever before observed. Many reports of debris falling at some distance from the path were received, including a report of cancelled checks coming down 165 miles distant. As this monstrous twister roared just north of the Richards-Gebaur Air Force Base through suburban Kansas City, hundreds of homes were leveled, 33 persons were killed, 170 were injured, and property damage was estimated in the millions.

Another death-dealing tornado of 1957 occurred at 1840CST, 20 June, at Fargo, North Dakota. Ten lives were lost, over a hundred persons were injured, and property loss was again measured in terms of millions of dollars. A total of 1,364 homes were destroyed or damaged. This tornado, like the Dallas and Kansas City occurrences, was observed from a weather station.

The effectiveness of short-range tornado



An action photo, from a 16-mm movie frame, shows a building which was lifted from the ground about two-thirds of a second earlier and is now breaking apart. Note that the dust funnel is about 100 feet ahead of the building (the tornado is moving across the picture from left to right). Object No. 2 is already partially obscured by the dust. Photo by Maurice Levy, NBC News.

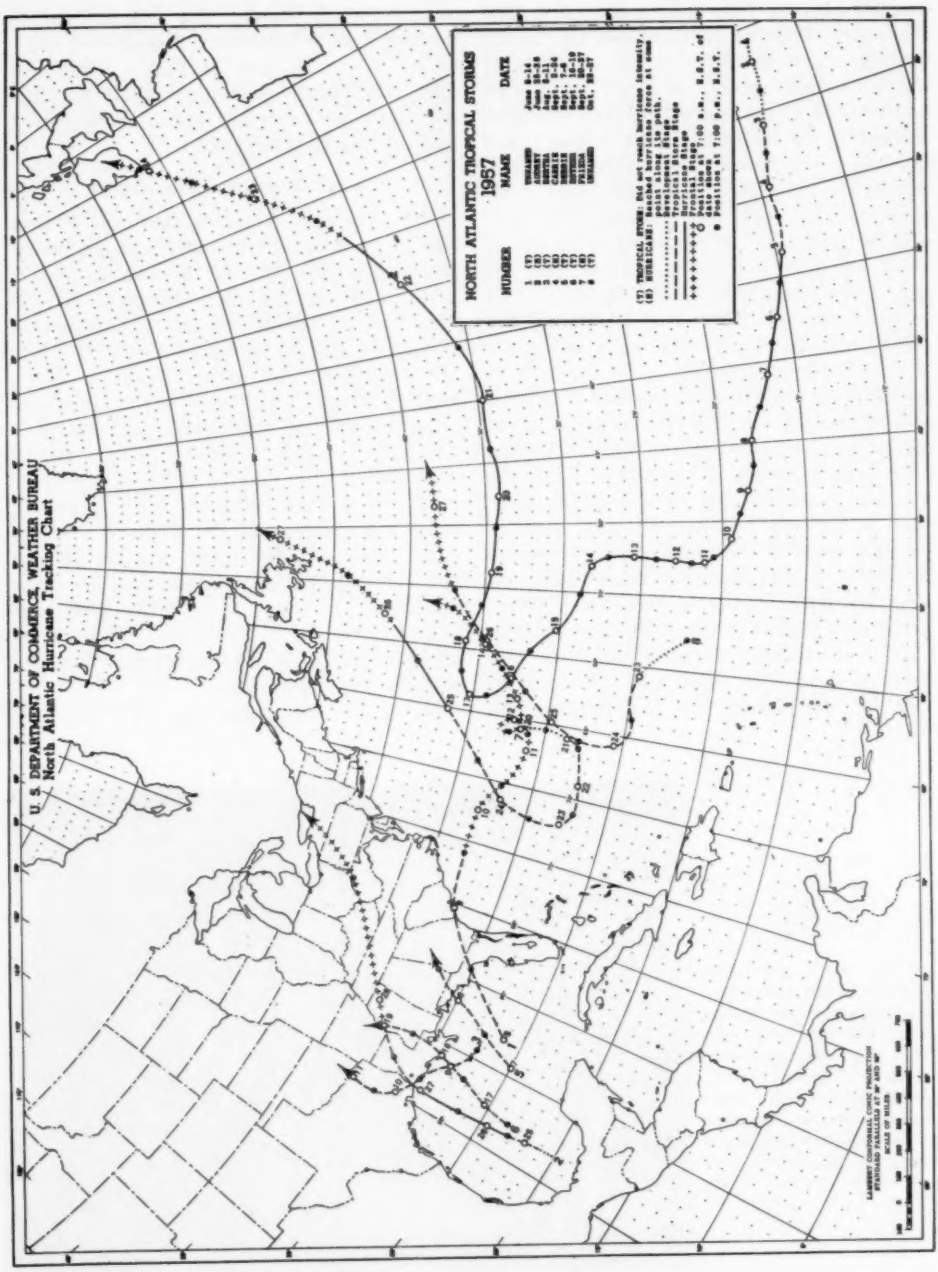
warnings from weather stations with rapid dissemination by radio and TV stations was demonstrated on three outstanding situations this year. The first of these was the Dallas tornado which formed over the outskirts of the southwest section of the city. This twister was first reported to the Weather Bureau by the Redbird Airport manager, and this report was immediately relayed by direct wire to the radio and TV stations there. Announcers could see the tornado from their vantage points at the studio or from mobile units and gave reports of position and apparent movement continuously during the life of the tornado. Films and photos of the Dallas tornado, along with some discussion of the problems involved, were shown at a special press conference in Kansas City later to demonstrate the life-saving potential of timely tornado warnings. When the Kansas City tornado struck a few weeks later, the TV and radio stations were well prepared. This storm was followed by the Weather Bureau's radar at the airport; since observers in Kansas had reported a funnel associated with this particular echo, frequent bulletins were issued regarding the location and movement of this storm. Excellent warnings were distributed by the radio and TV stations. There is no question but that hundreds of lives were saved by these warnings since about 500 homes were destroyed and interviews with witnesses showed that several hundred persons were in basements of destroyed structures. A month later, at Fargo, North Dakota, the effectiveness of tornado warnings was again demonstrated and the loss of life was substantially minimized.

1957 Tornado Research

The Tornado Research Airplane Project was plagued by instrumental and equipment problems during most of the tornado season. The major troubles were corrected late in May but on the fourth day of operational flying, an engine failure of the P-51 plane at Scottsbluff, Nebraska, forced an emergency landing. The engine was repaired and some operational flights were made in June and early in July. Another engine failure occurred just after take-off at Topeka, Kansas, on 7 July and an emergency landing resulted in serious damage to the airplane. Fortunately the pilot, Jim Cook, was not injured and the meteorological instruments were not damaged. In spite of the many difficulties this past season, 13 operational flights were made in which useful meteorological data for research were obtained.

(*Continued on page 37*)

A second photo, taken 1.5 seconds after the first, shows the movement of the various pieces. Note the wide distribution of pieces, which only two seconds before were a part of the same building. Photo by Maurice Levy, NBC News.


U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
North Atlantic Hurricane Tracking Chart
NORTH ATLANTIC TROPICAL STORMS
1957
NUMBER
NAME
DATE

The 1957 Hurricane Season

WALTER R. DAVIS, *U. S. Weather Bureau, Miami, Florida*

THE hurricane season of 1957 in the Caribbean-Atlantic-Gulf of Mexico area was fairly light in comparison to the past 15 to 20 years as regards the number of storms and hurricanes. Eight storms developed, three of which attained hurricane intensity. A normal season, at least for recent years, has been about 10 storms, with half of these developing into hurricanes.

Two main tracks were followed this year; one formed in the Gulf of Mexico and moved northward and northeastward to strike the Gulf Coast, and the other formed in the Atlantic but recurved northward and northeastward before affecting the eastern seaboard of the United States. Activity could be considered at a maximum in the Gulf of Mexico area, for five of the storms developed there and all moved into the coast between extreme east Texas and northwest Florida. Of this number, Hurricane Audrey was one of the most destructive June storms of record and was the first hurricane to occur in June since 1945. The other two hurricanes, Carrie and Frieda, formed and remained in the Atlantic, and never affected any land area until Carrie passed through the Azores.

AUDREY

Hurricane Audrey struck the Gulf Coast on 27 June near the Louisiana-Texas border with devastating effect. The formation of a tropical depression was first noted in the Bay of Campeche in the southwest Gulf of Mexico on the 24th, after a weak easterly wave had moved into the area a day or so earlier. Increased shower activity and changes in the wind field were in evidence, and a report received from a boat of the shrimp fleet confirmed the beginning of a well-organized storm. During the night the circulation increased rapidly in intensity and on the morning of the 25th, reconnaissance aircraft reported maximum winds of 85 knots and minimum sea level pressure of 989 mbs. During the afternoon, maximum winds encountered by reconnaissance aircraft were 75 knots and minimum pressure had dropped to 979 mbs. On the 26th the hurricane had increased some in size and intensity and maximum winds were up to 90 knots and the lowest pressure found to be 973 mbs. On the 25th and 26th, rainfall appeared to be fairly light in the hurricane area; however, a radar reconnaissance flight during the night of the 26th reported a considerable increase in the rain field. No readings of minimum surface pressures were received during the night. The only other reports of central pressure prior to landfall were received from the Tanker Tillamook in the vicinity of latitude 28.7 N, longitude 94.0 W during the early morning hours of the 27th. The lowest pressure reported was 969 mbs, which was in the western portion of the storm and does not reflect the minimum pressure at the center.

During the night of the 26–27th, Audrey increased in forward speed from about 7 to 15 mph and intensified considerably. The lowest pressure when Audrey made landfall was something of the order of 30 mbs lower than that last reported by reconnaissance aircraft. Readings of 960 and 966 mbs, respectively were obtained from the Calcasieu Coast Guard station, 20 miles east of the center, and Port Arthur, Texas, about the same distance west of the center. Computed minimum pressures consistent with reports of wind, storm surge, and damage indicate that the central pressure at time of landfall was between 914 and 958 mbs, probably about 940 mbs (27.75 inches).

The highest gust reported by a land station was 105 mph at Sulfur, La., which occurred before the instrument blew away. A velocity of 180 mph with a minimum pressure of 925 mbs (27.31 inches) was reported by an oil rig off the coast. These extreme values may have been associated with a tornado, since several were later reported in proximity of the hurricane. Observations obtained from four sea tenders which went adrift in the hurricane reported winds of 140 to 150 mph. The exact maximum velocity will never be known, but computations by a formula developed by Fletcher (1), using the difference between central and environ-

mental pressures as a parameter, give a value of 150 mph.

Over 500 persons are listed as dead or missing as a direct or indirect result of Audrey, mostly by drowning from the effects through the storm surge. Tides of as much as 10.6 feet above mean sea level were reported at Cameron, La., with possibly slightly higher readings in surrounding locations, due to funnelling in bays and the gentle slope of the continental shelf. A formula developed by Conner, Kraft, and Harris (2) for computing the probable height of the storm surge, as a function of the central pressure of 940 mbs, indicates a maximum surge of 12 feet.

A "hurricane watch" was issued two days in advance and hurricane warnings were ordered 14 hours before the high winds and high tides reached the coast. In spite of these warnings, in excess of 500 persons lost their lives. Property damage is estimated at $150 million. The death total was the greatest in United States since the hurricane of 1938 in New England.

Almost all property was destroyed in a 20 mile area from east of Cameron to the small towns of Creole and Chevanier and more than 60 per cent in an area 50 miles long extending 5 miles inland. In the Cameron to Grand Chenier area, 60 to 80 per cent of the houses were destroyed or floated off their foundations.

Hurricane Audrey gradually weakened and lost its tropical characteristics as she moved northeastward, but was still attended by rather strong winds on the 28th. Fourteen persons were injured in connection with tornadoes that formed southeast of the storm in Alabama. Some reintensification occurred when the remnants of Audrey reached the Ohio Valley and passed on through the eastern portion of the Great Lakes region. Some flood and high wind damage occurred in states south of the Great Lakes and eastward from western Pennsylvania through New York State. Pittsburgh reported winds of 65 mph and Jamestown, N. Y., had 95 to 100 mph in severe thunderstorms as a result of this intensification, which was no doubt due to extratropical processes.

Bertha

On August 6th a weak extratropical low moved into the northeast Gulf of Mexico and drifted slowly westward for the next 48 hours. It became of tropical storm proportions a short distance south of the mouth of the Mississippi River on the 8th, moved northwest and passed inland near Cameron, La., late on the 9th. Bertha did not develop to full hurricane intensity. Since she moved towards the same general portion of the coast that was devasted by hurricane Audrey in June, widespread safety precautions and evacuations were carried out. Ship reports and those from land stations indicate maximum winds of estimated 50 to 70 mph. At Beaumont, Texas, the wind reached 44 mph with gusts to 52. In Vermillion Bay, the highest reported tide was 4.7 feet. The heaviest rainfall was 10.73 inches at Livingston, Texas.

The storm weakened rapidly after passing inland and, turning northward into southeast Oklahoma on the 11th, caused heavy rains as the remnants moved eastward across Arkansas. Property damage was slight. Two deaths were reported in connection with Bertha.

Carrie

Hurricane Carrie was first spotted on the early morning of September 6th. Its existence was confirmed by the receipt of a succession of reports of rapidly falling pressure, increasing winds, and squalliness from the SS Africar Star. During the afternoon, a special, though delayed, 1600 GMT report was received from this ship giving an east-northeast wind of 92 mph and a pressure of 1001 mbs. A message received from Pan Air du Brazil on September 2nd said that a tropical storm cyclonic development was evident at approximately latitude 11 N, longitude 25 W. Observations received from the Cape Verde Islands indicate that a vortex probably was forming and passed a short distance to the south on this date. Little or no information was received from the area between the Cape Verdes and longitude 40 W during the subsequent three days until the African Star encountered Hurricane Carrie. Extrapolating back from latitude 15.5 N, longitude 39.5 W at around 12 mph indicated the vortex which passed south of the Cape Verdes on the 2nd was the genesis stage of Hurricane Carrie.

On the 7th the regular Air Force Gull reconnaissance flight out of Bermuda was diverted to the area and encountered maximum

winds of 138 mph at 700 mbs in the northwest quadrant. The eye was well-defined and 20 miles in diameter with minimum pressure at the center of 945 mbs. (27.80″). Using this central pressure, as obtained by dropsonde, and a formula developed by Fletcher (1), the surface wind was calculated to be about 130 mph. Reconnaissance on the next four days showed a gradual rise in central pressure; on the 11th the minimum pressure was 984 mbs and the highest winds were reported as about 70 mph. The weakening of the hurricane was probably due to decreasing pressure gradient to the north, as a low pressure trough formed across the subtropical high to a deepening low near Newfoundland. This low, moved southward, reaching its most southerly position on the 11th, after which it began a slow retreat to the north. Carrie had turned to a northerly course by this time and continued northward at 7 to 10 mph until the 14th when rebuilding of the high pressure ridge over the North Atlantic forced it to change course towards the northwest. This change in direction was accompanied by re-intensification and on the 12th the reconnaissance aircraft found highest winds of 108 mph and minimum sea level pressure of 960 mbs. There were heavy wall clouds in all quadrants with the exception of the southwest. It continued to increase in size and intensity. On the 15th the National Hurricane Research Project observers reported the storm as one of the most perfectly formed hurricanes they had observed. The surface winds of 138 mph which were observed on this date were the maximum during the life of Hurricane Carrie, but it is likely that equal or higher velocities occurred during the period of lowest central pressure on the 7th and 8th.

On the 16th, as the hurricane was passing to the east and north of Bermuda, the eye was rather poorly defined on radar. The storm appeared to be weakening with the eye reported from 40 to 70 miles in diameter. On the 17th, a trough with attendant cold front passed off the North Atlantic coast, moved very rapidly eastward, and forced Carrie to turn northward, then east and east-southeast. The high latitude trough deepened to the east of Carrie, together with a southeastward moving low center south of Greenland. The hurricane continued on an easterly course then gradually turned towards the northeast on the 22nd and 23rd.

Carrie maintained winds of near 100 mph for the next several days after passing abreast of Bermuda. On the 21st the German sailing ship Pamir encountered the storm southwest of the Azores and went down with the loss of 80 of her 86 crew members. The storm passed through the Azores the following day, however, the maximum wind and lowest pressure are not known due to insufficient reports at hand from that area. The hurricane began to lose its tropical characteristics thereafter, accelerated rapidly towards the northeast, and lashed the British Isles with high winds on the 24th and 25th, causing tremendous waves on the coast and floods over parts of the area.

Hurricane Carrie was charted over probably the longest track of record, approximately 6,000 miles, from its origin off the African coast to near Bermuda and back across the Atlantic to the British Isles. Aircraft reconnaissance of this hurricane was of unusual quality. The Air Force flights from Bermuda on the 7th and 21st went farther east than any previous hurricane reconnaissance flights and the initial flight on the 7th covered approximately 3,700 miles with almost 17 hours in the air. Although most of the life of this hurricane was spent outside the reach of the normal upper-air observational network, data collected by reconnaissance made it possible to anticipate and forecast Carrie's meandering path with reasonable accuracy.

Debbie

On September 5th a stagnant upper trough prevailed in the central Gulf of Mexico, and a weak easterly wave moved from the Caribbean into that area. By the 7th, a weak circulation had developed which moved northeastward and intensified sufficiently to just reach storm proportions before moving inland near Ft. Walton in northwest Florida, about 40 miles east of Pensacola, on the morning of the 8th. The highest winds reported were around 40 mph at St. Marks, Fla. A squall at Tampa caused gusts up to 52 mph. Tides of 2½ to 4 feet above normal occurred some 150 miles east of the center in Apalachee Bay. Some flooding occurred due to the high

(Continued on page 36)

The Plains blizzard of late March stalled the stream-liner Golden State Limited near Meade, Kansas. Wide World Photos.

Some Noteworthy Snows of 1956-1957

DAVID M. LUDLUM

AN EARLY NOVEMBER BLIZZARD ON THE WESTERN PLAINS

ON the last day of October a cold front pushed inland from the Pacific Ocean and crossed the Plateau and Rocky Mountains on 1–2 November. In its rear a Great Basin high built up rapidly while the storm center, now in western Kansas, regenerated and deepened considerably as cold air from the northwest was fed into its circulation by the strong high to the west. At noon on the 2nd the center was in the area where Kansas, Nebraska, and Colorado meet with a pressure of 996 mb (29.42″), while the high over Idaho built up to a pressure of 1032 mb (30.48″). Blizzard conditions (for the season) developed over adjacent portions of South Dakota, Wyoming, Colorado, Kansas, and Nebraska. At Cheyenne, Wyo., a mile of wind was clocked at 58 mph on the 2nd and 53 mph on the 3rd with temperatures ranging from 16° to 27° on these days.

Heavy snow accompanied the gale winds. The 12-inches which fell over parts of Colorado was whipped into huge drifts to create the worst blizzard conditions in the area since 1949. In Kansas dust and snow were mixed, and the weight of 9-inches of wet snow felled many trees when gale winds added to the stress. In the Black Hills of South Dakota a fall of 37 inches was registered in 32 hours. The Lead-Deadwood area had its most destructive snow storm in years as gigantic drifts blocked roads and stopped all means of surface communications. The mercury at Rapid City, S. D., hovered between 27° and 32° during the snow period.

The storm center moved almost directly northward to the Black Hills on the 3rd and then curved northwestward, all-the-time maintaining a strong circulation aloft. Surface winds to the east of the storm track were not high and precipitation was generally light over the eastern Plains.

THANKSGIVING LAKE SNOWS IN NEW YORK AND PENNSYLVANIA

A severe November storm crossed the Upper Lakes on 22 November with a central pressure down to 972 mb (28.70″) when over southeastern Ontario. Rain, which fell over the Lower Lakes region before the cold front passage, changed to snow as the cold air swept in. It was a straight west wind at the eastern ends of Lake Erie and Lake Ontario with a long fetch over relatively warm water. Local snow showers of the typical lee lake shore variety were set up and maintained for about 48 hours.

The industrial city of Erie, Pa., was buried under an official measurement of 27 inches at the CAA airport station on Thanksgiving Day, and totals ran higher at nearby localities. The entire city was paralyzed the next day, and it was not until Monday that business was resumed on a normal basis.

New York communities of lesser size were hit by even greater snows. At the usually snowy end of Lake Ontario the three-day storm piled up amounts in excess of 40 inches, and at the New York end of Lake Erie depths ran in the twenties after the storm.

RECORD JANUARY SNOWS IN COLORADO

Snowfall was frequent in southwestern Colorado during the entire month of January. Record totals were piled up and snow blocades made dramatic news headlines during rescue efforts. Considerable economic hardships resulted in isolated communities which found themselves cut off from the rest of the world for almost a week.

Grand Junction, a valley location along the Colorado River at an elevation of 4,849′, had its snowiest month in history with a total fall of 33.7″. Mountain locations had gigantic totals—Crested Butte (8,855′) received 146.5″ and measured a snow cover of

78″ on the 27th. An early storm at Crested Butte had deposited 35″ on 8–9 January, and at the end of the month from the 21st to the 31st, 49.5″ fell.

The end-of-the-month storm caused great disruption to rail traffic in the mountain passes between Colorado and New Mexico. A freight train, rescue train, and a work train were all stalled in and near Cumbres Pass at an altitude of near 10,000′. The crews numbering 60 men were isolated from the 26th and 31st. Army weasels and helicopters were pressed into service to feed and ultimately to free the men. Landslides and snow slides added to the hazards.

A LATE SPRING BLIZZARD ON THE PLAINS

The central and southern Plains experienced one of the worst spring blizzards in history on 22–24 March. It was a "warm" blizzard since temperatures ranged just below the freezing point during the period of high winds and precipitation. Western and central Kansas bore the full brunt of the storm, although it was felt from South Dakota to Texas and was considered among the severest storms on record for March in eastern Colorado and southeastward to the Texas Panhandle.

A cold front moved southward over Kansas on the 22nd of March changing a period of fog, light rain, and drizzle to a heavy, wet snow. By the morning of the 23rd a whole gale was sweeping the state. Winds on the 23rd at Dodge City reached 68 mph and on the 24th the peak gust was 70 mph. The average wind speed for a 24-hour period on the 24th was 43.5 mph. Total snowfall at Dodge City amounted to 17.5 inches and there were amounts over 20 inches at several Kansas locations. Snow drifts in the western counties reached 20 to 25 feet. In eastern Colorado the 60-hour storm caused large livestock losses; estimates ran as high as 12,000 head of cattle and sheep destroyed at a loss of $1 million. Livestock became caked with mud and frost, some dying of suffocation. Much valuable top soil was blown away and winter crops damaged.

In Texas the cold front swept in as a Norther with winds mounting to 80 mph. Amarillo had 11 inches of snow which continued to blow long after the precipitation had ceased, some drifts mounted to a depth of 30 feet. Some 4,000 persons were marooned on blocked highways, and ten deaths were attributed to the storm conditions. On the same day that the blizzard was gathering force in the northwest Panhandle, the temperature in the southeast of the state soared to 97° at Rio Grande City.

SOUTHERN SNOW

A fast-moving cold front raced across the central Gulf States on the night of 7–8 March. With rapidly tumbling temperatures, a light rain changed to snow and gave Mississippi, Alabama, and Georgia a brief snow storm. A trace was observed as far south as Mobile Bay in Alabama, and in southern Georgia almost to the Florida border. Birmingham's total of 0.7 inch was the greatest there since 1950. Maximum state totals follow: Mississippi (Russell and Union) 1.0″; Alabama (Rockford) 3.0″; Georgia (Cedartown) 1.5″; and Tennessee (Springfield) 4.0″.

A LATE APRIL SNOW IN THE MIDDLE ATLANTIC STATES

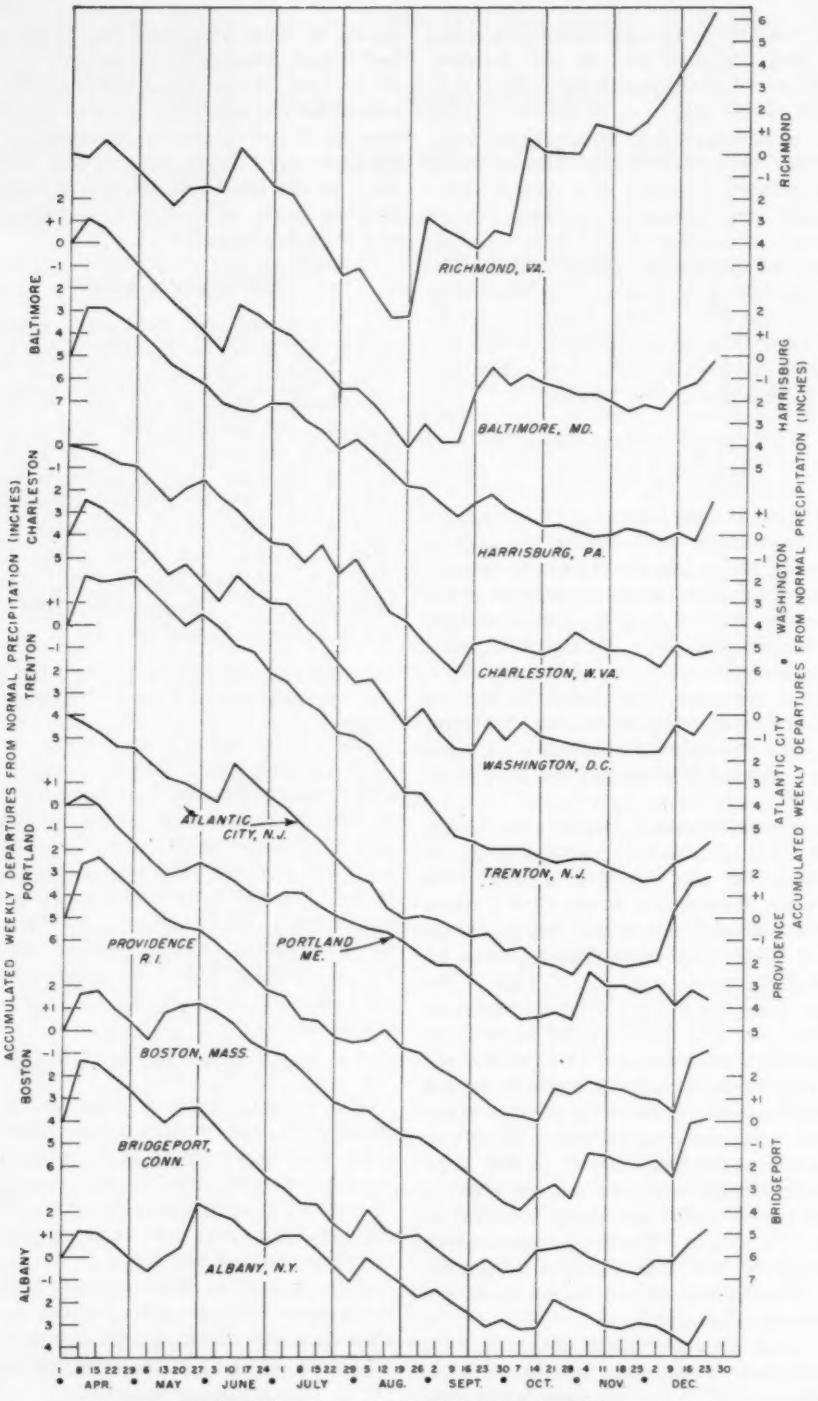
The coastal region from Virginia to Nantucket Island had a mid-April snow storm which was the heaviest in modern records for so late in the season at several stations. A cold front swept eastward at the same time a coastal low was offshore. Rain changing to snow dropped a white blanket from southern Virginia northeastward: Staunton, Va., 4.5″; Lynchburg, Va., 2.8″; Richmond, Va., 1.2″; Cambridge, Md., 2.5″; Bridgeville, Del., 1.5″; Atlantic City, N. J., 1.0″; and Nantucket, Mass., 0.7″.

APRIL MOUNTAIN SNOWS

The eastern slopes of the Rockies, the Black Hills, and western Plains experienced some very heavy snows in early April. At some points the snowfall was the heaviest of record for April—in eastern Colorado the accumulations were the greatest for any month in the past ten years.

Rain changed to snow on the first of April over eastern Colorado and continued for more than 30 hours, piling up depths which measured from 10 to 50 inches according to local-

(Continued on page 34)



Rainfall departures at selected cities during 1957.

Drought In 1957

WAYNE C. PALMER *Office of Climatology, U. S. Weather Bureau*

DROUGHT is a relative term. Those people who live in semiarid regions would consider a year with 30 inches of rainfall as a wet year—provided the rain was fairly evenly distributed and the bulk of it did not occur in just a cloudburst or two. On the other hand, the inhabitants of a humid region would be proclaiming "drought" if they received only 30 inches of rain in a year. Both opinions are perfectly reasonable inasmuch as they are based on such relative quantities as adapted local cropping types and practices and general local expectations. Basically, drought is a climatological event and is best considered as a relatively temporary climatic abnormality. If the economy of an area is geared to 40 inches of precipitation a year and in some year only 30 inches falls, that area has troubles of many kinds—poor crops, low reservoirs, and an all-around water shortage.

During 1956 there was grave concern over a severe to extreme drought in the central and southwestern United States (1). The year 1957, however, was abnormally wet over much of that area and drought was not a problem; attention had shifted to the eastern and northeastern part of the country where 1957 was the driest year on record at many places.

By late winter and early spring there was a growing realization that an incipient drought condition existed at some points in the Northeast. The very unseasonably high temperatures of late April (above 90° F in some places) added to the mounting concern over the shortage of spring rainfall. A rather detailed account of various drought aspects of the spring and summer has been published (2). For the benefit of those who may not have ready access to the *Monthly Weather Review*, the conclusions of that article are summarized in the following five paragraphs.

A. The Eastern drought affected primarily the coastal strip from southeastern Massachusetts, Rhode Island, and Connecticut, through southern New York, New Jersey, and eastern Pennsylvania, to Delaware, Maryland, and eastern Virginia. In general, conditions were less severe in the interior, though West Virginia and some other inland areas appear to have been hurt badly.

B. The drought began in mid-April; April 10th is frequently cited in the reports as the beginning of the dry spell. This was not too harmful agriculturally, because of the early stage of most crops and in view of the fact that it was alleviated in several areas by late-May rains. The important months of June and July, however, defined the worst drought area (as just described), and most of August intensified it. Good rains came to many areas in late August and early September (especially noteworthy being the 25–26 August coastal storm), but many localities continued to suffer from deficient moisture throughout.

C. The period of mid-June to mid-August may be taken, from both the climatological and the agricultural viewpoints, as the worst phase of the drought. The map of moisture deficiency represents conditions during this period fairly well, except in West Virginia. The evidence of the map is well supported by the rainfall figures and the streamflow and ground-water data. The reports of crop conditions, in general, bear out very well the conclusions regarding the duration and areal extent of the drought. If more soil moisture measurements were available, in addition to those cited, it would be possible to speak with more certainty regarding these points.

D. From the climatological and hydrologic standpoints, the drought was rather severe. The fact that so many Weather Bureau stations reported new record-low rainfall during the period, plus the near-record or record-breaking character of much of the streamflow data, indicates that, for the area affected and the time of year, it may be considered as unprecedented in some areas. Two qualifications must be quickly added to this blanket statement. The drought did not affect all parts of the Northeast equally, and some places may

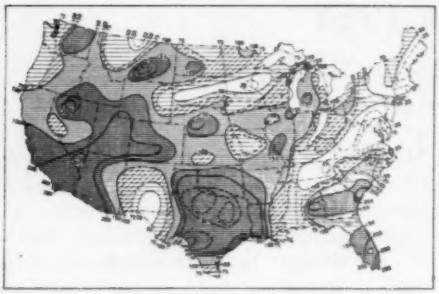


FIG. 2. Percentage of normal precipitation for four weeks ending 12 May 1957.

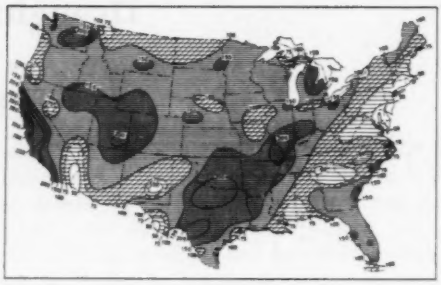


FIG. 5. Percentage of normal precipitation for 16 weeks ending 28 July 1957.

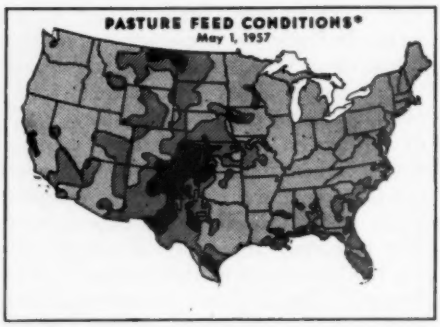


FIG. 3. Pasture feed conditions on 1 May 1957.

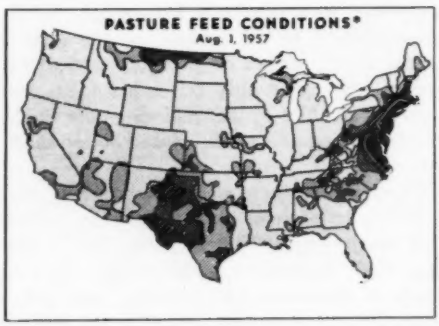


FIG. 4. Pasture feed conditions on 1 August 1957.

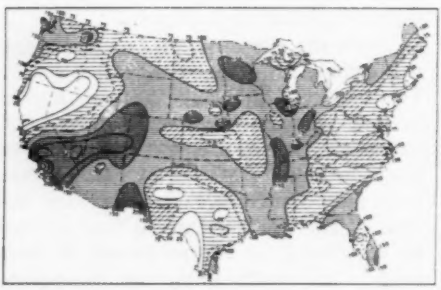


FIG. 6. Percentage of normal precipitation, summer (June–August) 1957.

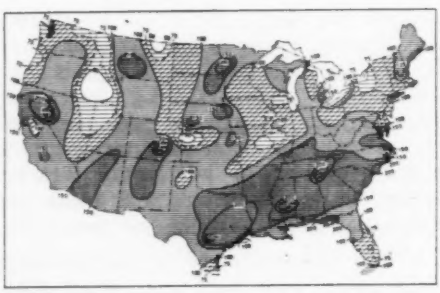


FIG. 7. Percentage of normal precipitation, fall (September–November) 1957.

have been troubled by it scarcely at all. On the other hand, even in the badly-hit areas, some localities may have been more grievously affected in the past. The second qualification is this: no precise evaluation of the drought in strictly agricultural terms is here attempted.

E. The severity of drought depends on both the magnitude of the moisture deficiency and its duration. The drought in the Northeast during the spring and summer of 1957 was without doubt very intense during these few months, but its severity is hardly comparable with many other droughts which have affected other areas of the United States in the past—droughts in which the duration was measured in years rather than months.

At the time the above account was prepared the drought had shown signs of ending in some places, particularly along the central Atlantic Coast; much of the Northeast, however, was still in need of water.

Figure 1 shows the progress of the 1957 rainfall deficiency at 12 points between Richmond, Virginia, and Portland, Maine. The 12 curves in the figure represent for each city the accumulated weekly departure from normal rainfall from 1 April to 23 December 1957. For example, at Baltimore, Maryland, the rainfall during the week ending 8 April was 1.93 inches, which was 1.09 inches more than the normal amount for that week; so the Baltimore curve shows an excess of 1.09 inches by 8 April. Rainfall during the 2nd week in April was 0.39 inch less than normal; so by April 15th accumulated excess was 1.09 inches minus 0.39 inches or 0.70 inches. By 19 August rainfall had been less than normal during every single week since 8 April except for the week of 4–10 June and the accumulated deficit had reached a value of 9.09 inches since April 1st.

It is readily apparent that as long as the weather continues drier than normal the curves slope downward to the right, but as soon as rainfall becomes normal or more the curves level out or start to climb. From the slopes of such curves it is possible to determine rather closely the dates of beginning and ending of the unusually dry periods. It would be reasonable to say that at Baltimore the worst of the dry period began about 8 April and lasted until the week of 20–26 August. Actually the drought at Baltimore was broken by 1 to 2 inches of rain on August 25th. On the other hand, Atlantic City, New Jersey, received very little rain from the storm of 25 August and its deficit accumulation continued at a fairly rapid rate until 28 October.

At this point it is important that the distinction between meteorological drought and the *effects* of drought be kept in mind. At Atlantic City most of the weeks since 28 October have been wetter than normal; so the temporary shift of climate toward aridity has apparently ended. However, this does not end the effects of the temporary abnormality ; the damage to agriculture has been done; wells, streams, and reservoirs will remain low for some time.

The extent of the moisture deficiency at or near spring planting time is shown in figure 2. A number of areas in the United States had received less than half of normal precipitation during the preceding four weeks.

Figures 3 and 4 indicate the effects of the drought on pasture conditions. Note particularly the deterioration in the East by August 1st.

Figure 5 shows that the 16 weeks from 8 April to 28 July—which cover an important portion of the growing season—provided less than three-quarters of normal rainfall in many areas, with two fairly large areas in the East receiving less than 50 per cent of expected. By this time it was apparent that the non-irrigated crops in these drought areas had little or no chance of producing a profitable crop.

The summer months of June, July, and August were unusually dry in a number of rather large areas (fig. 6). There was some concern that the drought might have returned in Texas and the very dry area in the West had produced extreme forest fire danger.

From figure 7 one can see that, in general, the places most in need of rain have received fairly good amounts during the fall and early winter.

Returning to figure 1, it is interesting to note the tendency for the ending of the drought to occur progressively later from south to north: Richmond, mid-August; Washington and Baltimore, late August and

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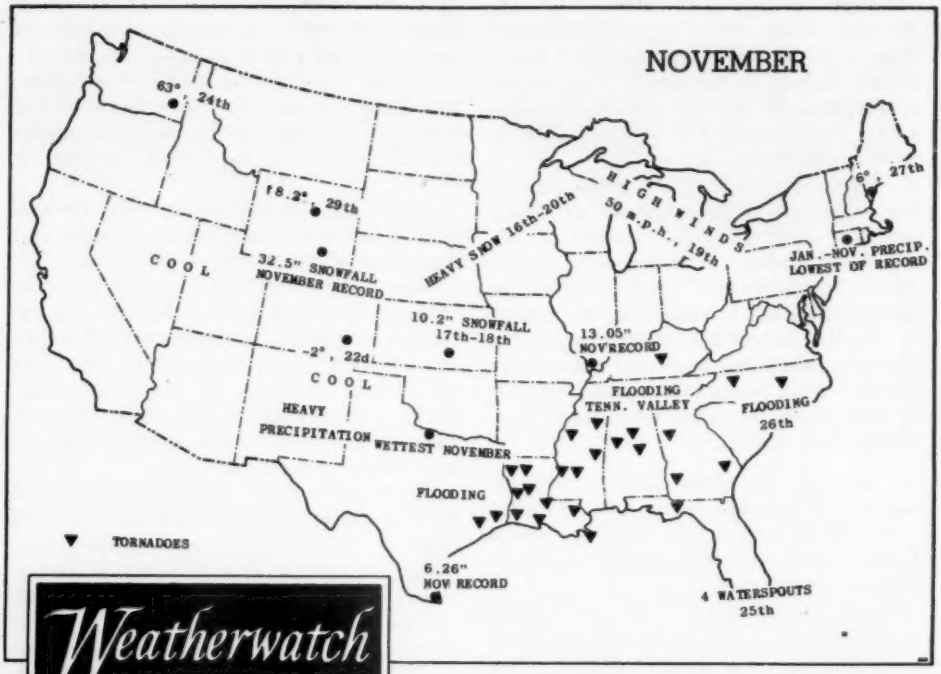


Data by Office of Climatology, USWB.

Westerly Flow Increases as Winter Commences

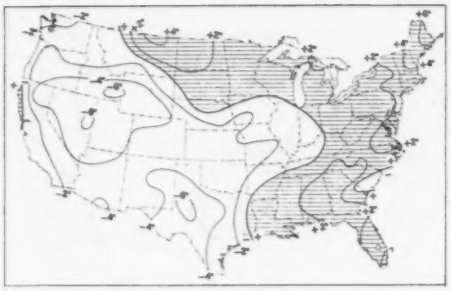
DAVID M. LUDLUM, *Editor*

The final two months of 1957 featured a progressively warmer than normal temperature trend in contrast to the below and much below normal conditions which had existed country-wide in October. As a result, December was a very warm month for the nation as a whole, the first such month since February 1957.

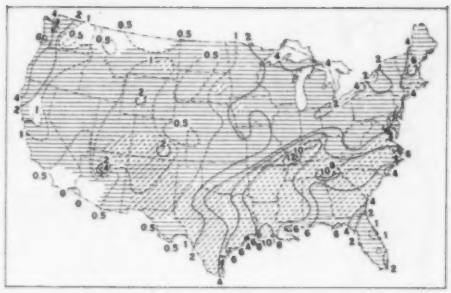
The blocking effect of the ridge of high pressure over northwestern Canada, long a major influence on circulation maps, gradually diminished during the month, permitting a speed-up of the westerlies and a flow of mild Pacific air to invade the continent. This major shift in circulation occurred at the commencement of the last week of November. Thus, the first month of winter 1957–58 averaged above normal everywhere with the two exceptions being the reputedly winter resort areas of the Florida peninsula and the interior of California.

NOVEMBER CIRCULATION—The ridge of high pressure over western Canada and adjacent parts of Alaska had been a major feature on most all monthly upper-air mean charts since the commencement of 1957. Herein lay the key to the weather circulation for the first ten months of the year—a low index of westerly air movement which largely shut out Pacific air masses from the continent and favored the entry of polar and tropical air streams. With their greatly contrasting thermal content, these air masses battled for possession of the great central valleys of the United States and produced many spectacular weather events during 1957.

During the first three weeks of November a trough through the Mississippi Valley produced the main weather features of the month. A northwesterly flow into the trough continued the regime of cold weather in the Plateau, Rocky Mountains, and central and southern Plains, but east of the Mississippi River it was warm in the southwesterly flow on the eastern flank of the trough. After 23 November, however, a new feature appeared on the circulation maps—the Plateau high, a frequenter of winter weather maps, took a commanding position over the Great Basin area, replacing the western Canadian ridge as the principal steering agency for air streams moving from the West. Now Pacific air could flow in over British Columbia, cross the Rockies, and descend into the central valleys as a mild, dry air stream. A vigorous low pressure area



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

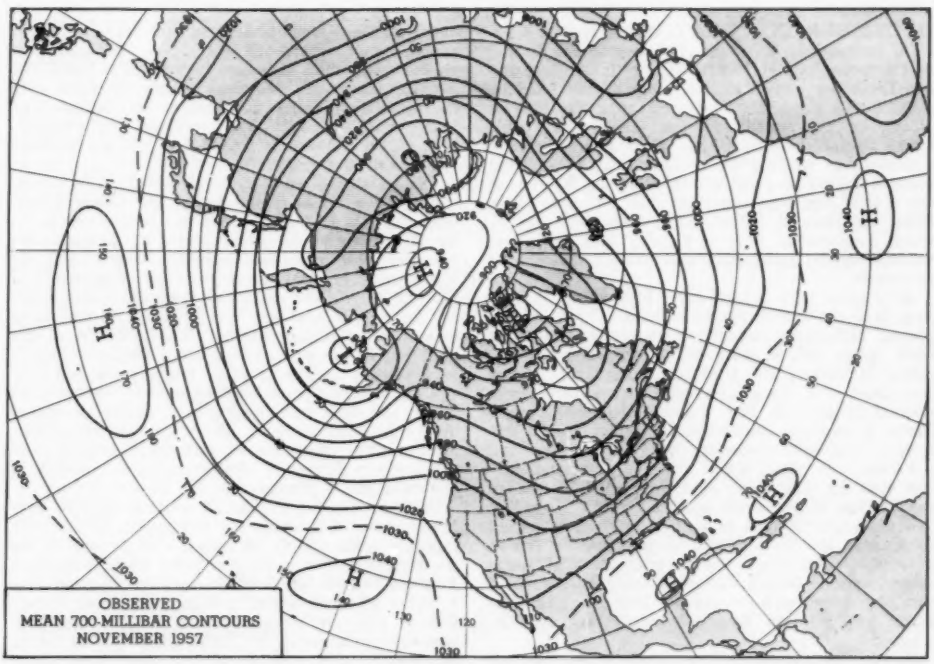
in the Aleutian-Gulf of Alaska area sent frequent pressure impulses eastward across Canada and the northern United States during late November.

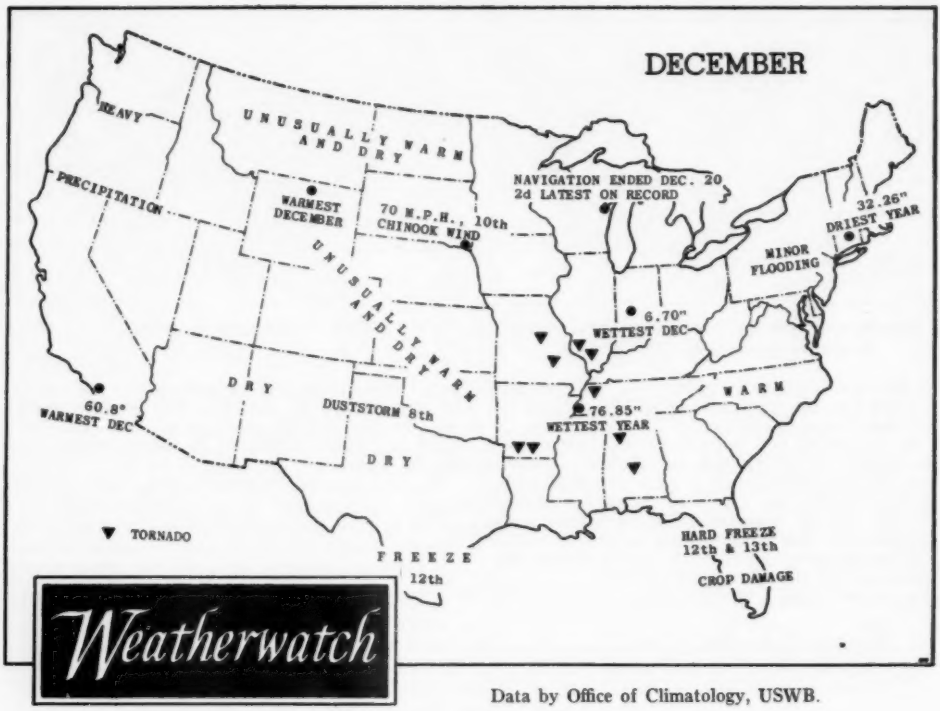
In November two main storm tracks traversed the United States: (1) from the Oklahoma-Arkansas area northeastward toward a polar vortex in northeastern Canada, and (2) from the eastern Gulf of Mexico and the Southeastern States east to Cape Hatteras and then northeastward toward Greenland. Two severe storms generated in the Mississippi Valley trough on the 14–16th and 18–19th to affect all the eastern portions of the continent. These comprised the only major storm outbreaks of the month. So effective was the blocking effect of the western ridge of high pressure that only one low center entered the United States from the Pacific Ocean during the month.

The precipitation pattern reflected the general pressure distribution. It was an outstandingly wet month in many parts of the country with moderate to heavy totals everywhere except in eastern Florida, the northern California coast, and the Northwestern

(*Continued on page 30*)

The upper-air map below shows the pattern of air flow for November at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.





Data by Office of Climatology, USWB.

DECEMBER CIRCULATION—The trend toward an increased speed-up of the westerlies, noticed in the latter half of November, continued throughout December. With the recession of the blocking ridge in the Canadian Northwest after the 20th of November, the pressure gradient across the Pacific Ocean tightened considerably. Thus, a fast westerly stream swept in long waves across the Pacific and plunged inland to penetrate far into the interior of the North American continent. It was zonal flow along the lines of latitude rather than the north-south, longitudinal flow of October and early November which determined the weather pattern of December.

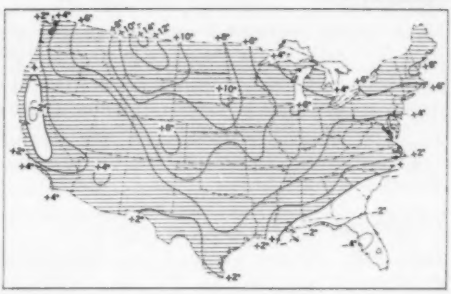
As is usual with a high index of westerly circulation, both the central Pacific high and the Bermuda-Azores high were strong and somewhat north of their mean winter positions. A marked cyclonic center dominated the Gulf of Alaska area, and it was there that the greatest minus departures from normal pressure in the Western Hemisphere were found throughout December. A minor trough extended south-southeastward from Alaska well off the California coast, but it was not of great depth. Nor was the ridge lying over the Pacific States and the Plateau of significant posture.

Trough after trough broke away from the parent cyclone in the Gulf of Alaska and pushed inland over North America. The favorite track of storm centers entered British Columbia and then undulated east and southeastward passing between Lake Superior and Hudson Bay, a normal track for December.

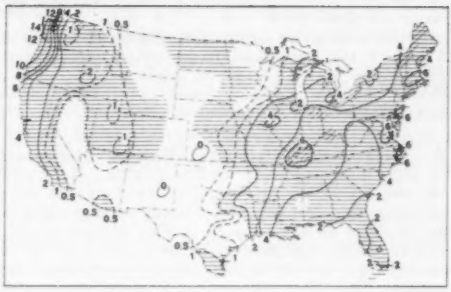
Another important storm path of the month originated in the Kansas-Oklahoma area with the main movement northeastward over Lake Michigan to a polar vortex which remained in the Baffin Land area most of the month. A mean trough remained over the Mississippi Valley to separate the Plateau ridge from the Atlantic high, but it was not of the magnitude of the November trough and did not produce comparable storminess.

The jet stream at lower levels appeared in a normal position for December across the Lower Lakes. Cold air was mainly confined to Arctic regions by the strong westerlies across southern Canada. Except for one important exception, when cold air streamed all the way across the Gulf of Mexico and Florida, there were no widespread polar outbreaks, so the month averaged much above normal in a large portion of the nation. The influence of the mild Pacific air and its downslope chinook-effect is very evident on the monthly temperature and precipitation maps: from Washington southeastward to Texas and then northeastward to Maine, it was a very mild winter month. In fact, it was the warmest December on record in northern Wyoming; and the mercury averaged 14 degrees above normal in Montana and 8 degrees above in Maine.

With cool, moist Pacific air moving onshore very heavy rains fell along the Northwest Coast with monthly totals up to 14 inches. So it was in the southwesterly flow in the Northeast where some New England and Middle Atlantic locations received over 6 inches of much-needed precipitation. But the effect of the rain shadow of the Rocky Mountains was very apparent in the Plains where it was a very dry month after a series of wet ones—some places



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



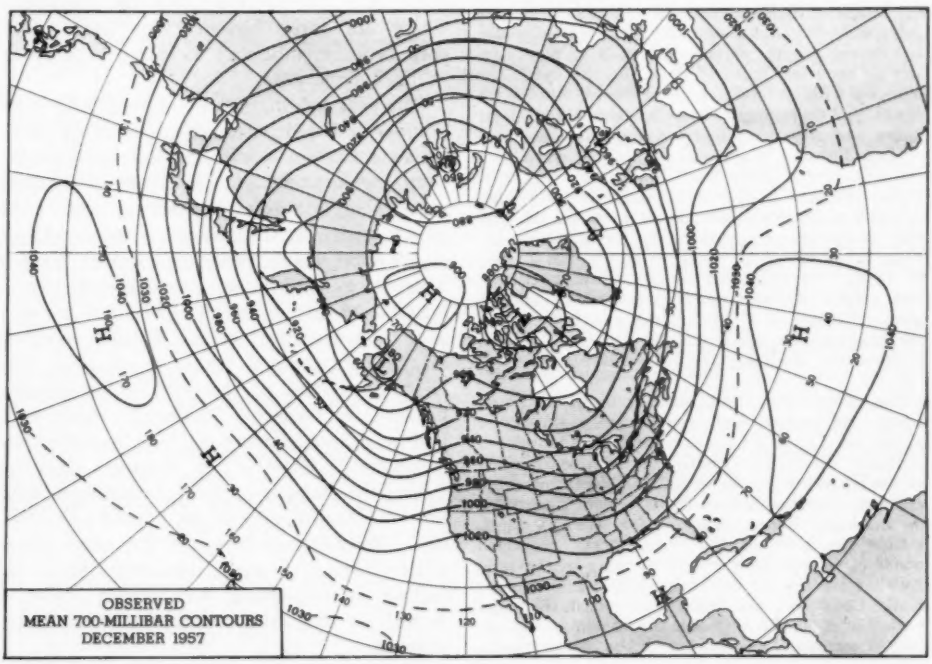
Total Precipitation in inches. USWB chart.

in Kansas and New Mexico had no measurable precipitation.

FLORIDA FREEZE—The single exception to the December circulation regime occurred from the 10th through the 13th when a strong polar anticyclone with a central pressure of 1048 mb (30.95″) crossed the Montana border and plunged directly south to Texas. The preceding cold front entered northwest Florida early on 11 December and cleared the southeast coast by mid-afternoon. Meantime the anticyclone had reached the Texas-Louisiana area (pressure 1036 mb or 30.60″), a position from which it could continue to pump cold northwest winds into the Florida Peninsula with a minimum of modification of their frigidity.

Under clear skies on the nights of the 11–12th and 12–13th the mercury plunged to and remained for some hours at dangerous levels: 12° to 27° in the north, and 32° to 37° in the Everglades in the south. In the central portion of the Peninsula, including the west coast, readings of 26° or lower persisted from 5 to 11 hours. Winds made protective measures difficult and largely ineffective.

The severity of the December 1957 freeze approximated the degree of the more recent historic freezes of December 1934 and January 1940, but by no means equaled the "great" freezes of February 1835 and the winter of 1894–95, when a major portion of the citrus trees were killed. Damage to the citrus industry was estimated at $100 million with huge losses as well to the more vulnerable truck farming industry. Losses from the tourist trade as a result



of cancelled reservations and curtailed outdoor activity are incalculable.

Unfortunately, as occurred in December 1894 and February 1895, a second freeze struck Florida just four weeks later on 9 and 10 January 1958 under a similar pressure pattern. Losses were expected to equal those of the December disaster.

A MID-WESTERN STORM—A disturbance of large proportions struck the central portions of the country on 18–19 November and spread a path of destruction and death over many states. At least 14 fatalities were attributed to the mixture of tornadoes, floods, thunderstorms, line squalls, and heavy snows which enveloped the eastern two-thirds of the nation. November has produced many memorable storms and that of 1957, although not in the "great" category, had many interesting features.

Following an active cyclonic disturbance of the 15–16th, another trough from the Pacific crossed the Rockies on the 17th and soon joined forces with a low pressure center which lingered in southwest Texas from the previous trough. A wave shot rapidly up the trough along the cold front to reach a position in northwestern Arkansas early on the 18th with a central pressure of 1004 mb (29.65″). By noon of the 18th with the center speeding to central Illinois, cold air was feeding into the rear of the whirl as warm Gulf air continued to stream into its forward section. Rapid deepening took place, and a major storm developed. Tornadoes and heavy rains lashed the area east of the Mississippi River on the afternoon of the 18th, spreading havoc from the Gulf of Mexico to the Lakes. Hopkinsville, Kentucky, the recpient of 8.57 inches of rain in the two storms, experienced a major flood as tornadoes and heavy thunderstorms lashed the vicinity. Severe thunderstorms occurred all across the Southeast as far as Georgia.

By early morning of the 19th the vigorous center had moved directly north to Green Bay, Wisconsin, and by noon was north of Lake Superior near Lake Nipegon with a central pressure down to 976 mb (28.84″). Gale force winds lashed all the Great Lakes and were particularly damaging to shipping on Lake Superior where a major blow occurred. To the west of the storm track heavy snow fell from Upper Michigan to Texas; in southeastern Minnesota and northeastern Iowa up to 15 inches fell, and five inches were reported in the Texas Panhandle. Light snow fell as far south as Austin and Laredo in Texas. The frigid air in the following circulation droped the mercury in northwestern Texas to zero and below: −1° at Lubbock and Dalhart. In the Rockies early winter struck with −24° at West Yellowstone, Montana, and −35° at Fraser, Colorado.

The storm center continued a direct northerly track. Its progress had been originally slowed by a 1048 mb (30.95″) high over Baffin Land, and this probably contributed greatly to the intensification of the low center on the 18th. The cold front swept eastward over the Eastern States attended by winds of hurricane force. Morgantown, West Virginia, astride the crest of the Appalachians, registered winds of 92 mph early on the morning of the 19th. By that evening the cold front had cleared the Atlantic Coast and the center had joined the polar vortex over northern Quebec. This ended the period of storminess associated with the central trough.

November (*Continued from page 27*)

States. In the Northeast it was the wettest month since April and the copious precipitation did much to restore reservoir levels after the record dryness of summer 1957. It was the wettest November on record at such diverse points as Cairo, Illinois; Winston-Salem, North Carolina; and Brownsville, Texas. In the Rockies and Plains much snow fell—Lander, Wyoming, reported its snowiest November of record.

Progress (*Continued from page 5*)

twice-daily 250-mb analyses and four-times-daily wind analyses at 30-, 40-, and 50-thousand feet. At the 10th Technical Conference of the International Air Transport Association held in Miami last November, the conferees took cognizance of some of the high-level-forecast problems and included on their agenda a discussion of the meteorological requirements for turbine-powered aircraft.

Activities of the Society

The number of local branches of the Society increased from 41 to 48 in 1957. Our membership increased by 638 during the year, and reached a total of 6523 at the end of 1957. Of the present membership, 2068 were regular members, 3028 were professional members, 161 were student members, and 1194 were associate members. There are three honorary members. Our corporation membership increased from 56 to 69 during the year.

The year was marked by an unusually high number of important meetings of the Society. There were two workshops, one on agricultural meteorology and the other on applied meteorology. Special conferences, some held jointly with sister organizations, were held on severe local storms, radar meteorology, hydrometeorology, bioclimatology, atmosphere pollution, and the upper-air. The Society was actively represented at the Toronto meeting of the International Union of Geodesy and Geophysics, and at the 9th Pacific Science Congress in Bangkok, Thailand. Plans were laid for a joint meeting with the Scandinavian geophysical societies, in Bergen, Norway, during the summer of 1958, to commemorate the 40th Anniversary of the Polar-Front Theory. At the same time, the Executive Committee began to make tentative plans for further joint meetings with foreign societies as well as with groups concerned with fringe sciences.

The Executive Committee studied the pressing need of the Society for more adequate space at the headquarters of the Society. It was soon apparent that a campaign to raise a sizable amount of funds is necessary and, further, that to raise funds successfully requires the preparation of a carefully thought-out program for the next five to ten years' activities of the Society. Development of the AMS Program was begun at the three-day Council meeting held in Boston in October.

Two important Boards were established during the year. The Board for Certified Consulting Meteorologists seeks to insure high levels of capability and professional ethics on the part of that segment of our membership concerned with providing technical consulting advice to private clientels. The Board on Radio and Television Weathercasting aims at assuring that broadcasts of weather programs by members of the Society are of the highest attainable professional and ethical standards. Both Boards devoted much time and intensive effort during 1957 to establishing ground rules and methods of operation, and they plan to go into full-scale operation in 1958.

The Society commenced a program of issuing annual authoritative statements during 1957. These statements are designed to keep the layman up-to-date on important technical matters with which the meteorologist is concerned. They deal with either particular capabilities of the practicing meteorologist or with the current status of meteorological matters of special interest to the public. Statements issued so far deal with weather forecasting; weather modification; detection, tracking, and prediction of tornadoes; relations between solar activity and weather; meteorological aspects of radioactive fallout; and the use of earth satellites in meteorology. The very favorable response justifies continuation of the program which calls for an annual review of each and appropriate modifications. The Society also began its program of publicity surveys of special meteorological sub-fields in the *Bulletin* for the benefit of our profession as a whole.

In accordance with the Council's desires, as expressed in October 1956, the Society took positive stands and appropriate action on several matters which cut across the boards of the several segments of our membership. Among these were the failure of the U. S. Civil Service Commission to include meteorologists among government employees receiving special salary benefits, and the severe cutbacks in basic meteorological-research support on the part of the government in the fall of 1957. Responses from AMS activities of this sort provides ample justification for continuation of our program of speaking for the profession and science to the public and agencies whose actions affect our membership or field. The program is beneficial not only to individuals but also to the many meteorological agencies, private and governmental, which exist in this country. It is quite evident that we must be even more aggressive. We must clarify the role of the meteorologist in this age of expanding horizons and rising physical ceilings. We must increase our efforts to insure that meteorological practices in this country are competent and honest. Through promotion of research and development we must do all we can to see that our professional people keep up with the rapidly expanding requirements for meteorological (and associated geophysical) services and support. We must add to the public's knowledge of and appreciation for meteorological matters. We must increase our efforts to attract potential growing scientists and technicians to our field. Your Council and Executive Committee feel that the Society is off to a good start in these directions. This has been possible only because of the active, selfless participation in Society affairs which so clearly characterize our membership. From the results so far evident, there is no question but that continuing participation, by a growing membership, will pay great dividends indeed to the whole of our expanding science and profession.

Circulation (*Continued from page 11*)

ing was associated in part with an abrupt northward shift of the mean jet stream at the 200 mb level. This is illustrated in figure 6, which gives the location of the principal jet axis computed from a series of monthly mean 200 mb maps. Whereas the mean jet was located near northern Mexico and southern Texas during the three spring months, it traversed the northern Plateau and northern Plains during June. This shift was reflected in displacement of the area of worst weather (tornadoes and floods) from the southern Plains during May to northern portions of the Plains and Mississippi Valley in June. A northward shift of the jet stream occurred also in the eastern part of the country, but to a lesser degree and in a more gradual fashion. There, too, it was accompanied by general surface warming, with parts of the Northeast changing from below normal temperatures in May to above normal in June.

Thus, June was a transition month in which the weather and circulation pattern of spring was replaced by one more typical of summer. The establishment of a summer regime culminated, during the last week of the month, with the passage of hurricane Audrey and rapid eastward motion of the mean trough which had been located in the central United States during most of June. At the same time a new trough extended along the West Coast, and a mean ridge developed over the Rockies. These events marked the initiation of a new circulation regime which was to dominate the months of July and August.

The mid-summer circulation pattern at upper levels is well illustrated by figure 7, the monthly mean 700 mb chart for August 1957. Of special importance are the two vertical lines delineating the location of mean troughs off both the east and west coasts of the United States. These troughs and the accompanying strong ridge and high center in the central United States were remarkably stable, and successive 5-day mean maps revealed only minor shifts in the long wave pattern throughout the months of July and August. This wave train was also well established at the 200 mb level, as illustrated by the location of the July jet stream in figure 6, with its sharp anticyclonic curvature and northward displacement in the center of the country, and its cyclonic curvature and southward shift in the mean troughs along either coast. Another stable and well-marked feature of this summer's general circulation was the deep low in the Arctic Ocean northwest of Alaska, where an already intense July polar vortex deepened to a remarkable mean value of 420 ft below the normal 700 mb height in August (fig. 7).

The extreme persistence of the long wave pattern over the United States during July and August was reflected in persistence of the weather anomalies. Surface temperatures averaged above normal under the upper level ridge in most of the area between the Rockies and the Appalachians. To both the east and west the coastal troughs were effective in producing below normal temperatures, except for the coasts of California and the Middle Atlantic States where warming resulted from abundant sunshine, down-slope motion, and weakening of the sea-breeze regime.

Precipitation during July and August was reasonably plentiful in many parts of the country. On the northwest coast it was caused by frontal activity and forced ascent of cool, moist, maritime air. Showers in the western moist tongue spread in a wide band from Arizona and New Mexico northward through the Rocky Mountains and western Plains and eastward through the Great Lakes to northern New England. Some of the moisture also eddied anticyclonically over the Middle Mississippi Valley, where as much as twice the normal amount of rainfall was recorded. In the Southeast showers were associated with quasi-stationary frontal activity and cyclonic circulation aloft.

Dry weather prevailed in the remainder of the country, with the outstanding abnormality along the Atlantic seaboard. From Massachusetts southwestward to the southern Appalachians rainfall deficiencies during the most important part of the growing season approached or exceeded all records. The lack of precipitation in this area during July and August could be directly associated with the off-shore trough and the dry northerly and northwesterly components of flow which prevailed at all levels. During spring, when the circulation was reversed, the central United

States trough was too far west and the ridge along the East Coast too strong for significant precipitation. The transition from one regime to the other was sharp and rapid with little opportunity for effective relief. Some relief was provided, however, during the last week of August by a small storm traveling up the coast during a period of large-scale retrogression of the planetary wave train.

Fall

The onset of the fall season was marked by another sharp circulation reversal. During September the planetary wave train became remarkably akin to that of June, with a trough again in the middle of the United States and the coastal troughs of July and August supplanted by ridges. As a result, temperatures increased by 3 or 4 classes from August to September in the Northwest and Northeast. On the other hand, temperatures dropped to below normal values in most of the area lying between the Rockies and the Appalachians as a consequence of frequent intrusions of polar Canadian anticyclones under cyclonic flow aloft. The lowering of temperatures along the Gulf coast and in part of the Southeast, despite increased southerly flow, was partly the effect of less sunshine than normal as record precipitation amounts fell in many sections. This rainfall was influenced greatly by several tropical storms moving inland from the Gulf in southerly flow ahead of the mean trough. However, record rainfall in the South did not spread far enough north to ease the drought in the Northeast, where Boston reported the first nine months of 1957 as the driest in 140 years.

During October the circulation again reverted to the pattern of mid-summer, with deeper than normal troughs becoming reestablished along both the east and west coasts of the United States and a ridge over the Great Plains (fig. 8). This month, however, the central ridge was quite weak, but a strong ridge was located over western Canada, with attendant positive 700-mb height anomaly center of 350 ft over the Yukon and secondary center of 260 ft near western Hudson Bay. This was a typical blocking ridge, with below-normal heights and a trough directly to its south, and with the primary jet stream split into two branches around it. At the same time the upper level westerlies were slower than normal over middle latitudes of the eastern Pacific and North America. In fact, the zonal index at the 700-mb level in the Western Hemisphere was at its lowest value for any October since comparable data was first computed in 1944. The dominance of blocking and low index during October permitted outbreaks of cold polar air from Canada to invade the United States at frequent intervals. As a result, both 700-mb heights and surface temperatures averaged below the October normal over nearly the entire country. Many new records for early season low temperatures and snowfall were set at widely separated locations.

Well above normal amounts of precipitation were observed during October over most of the western two-thirds of the nation because of the abnormally deep mean trough along the West Coast (fig. 8) and southward displacement of the jet stream. As much as 700 per cent of normal rainfall was reported from parts of normally dry Arizona and Colorado. West-northwesterly flow from the Continental Divide eastward across the northern third of the nation and concomitant anticyclonic curvature tended to inhibit precipitation from the Dakotas eastward through New England. In the Southeast it was generally dry, but in the Middle Atlantic States an intense Chesapeake Bay storm produced excessive rain on the 5th and 6th.

The weather and circulation of November in the United States were dominated by a single deep trough over the central portion of the country. Surface temperatures averaged below normal in the northerly flow to the rear of the trough and above normal in the southerly flow to its east. The marked thermal gradient thus established gave rise to frequent storminess and heavy precipitation over much of the eastern two-thirds of the nation. Several intense cyclones developed in Texas and moved northeastward through the Great Lakes to James Bay. These storms were accompanied by damaging tornadoes and floods in the southern states from Texas to the Carolinas and by heavy snows in the northern states from the Rockies to the Great Lakes. This was the wettest November on record at Cairo, Illinois; Brownsville, Texas; and Wichita Falls, Texas;

while 32 inches of snow set a new November record at Lander, Wyoming.

December was characterized by a rapidly rising zonal index (fig. 1). Abnormally fast westerly flow flooded the United States with mild Pacific air, while the cold polar continental air masses were contained in Alaska and Canada. As a result, above normal temperatures prevailed over practically the entire country. In this respect December 1957 was remarkably similar to December 1956, which was also dominated by fast westerlies and mild temperatures throughout the United States. Thus, 1957 ended as the previous year had, with a typically high index weather regime.

Snow (*Continued from page 21*)

ity. Roads were closed, power lines downed, roofs collapsed, and trees were stripped of limbs. Both Pueblo and Denver measured 17 inches and Colorado Springs had 20 inches of new snow. Mountain areas just east of the Divide received abundant amounts; Allenspark 38 and Lake Moraine 54 inches.

To the north in Wyoming, Lander had 19 inches on the 1–3rd, and Cheyenne 13 inches. Sunshine (6,835′) added 28 inches on the 1–3rd and 16 more on the 6th. South Pass City (8,005′) reported a total of 78 inches during April.

Heavy wet snow fell over South Dakota from the morning of the 3rd to the 5th at Rapid City. Nearby Hot Springs had 17 inches in this storm and a monthly total of 30.5 inches.

THE EARLY NEW ENGLAND SNOW SEASON

The snow season of 1955–56 in New England commenced early and by the end of January promised to approach record accumulations, but February turned mild with no major storm activity and the early spring months followed this pattern also. In fact, Portland, Maine, received 80 of its total 90 inches snowfall prior to 1 February. The falls there in December of 35.5 inches and in January of 35.3 inches were impressive and pointed toward new records. Most New England points, however, measured their maximum depths at the end of January. Hiram, in southern Maine, had 44 inches; Woodstock, N. H., 38; and Woodstock, Vt., 36—all low-level stations.

December produced a series of storms which were usually a combination of wet snow, sleet, and glaze across different zones. The storm of the 14–15th gave amounts up to 12 inches in the North. The only genuine general snow storm occurred on 29 December when a northeaster brought snow to the whole region. A low developed with unusual speed off the New Jersey coast and swept coastal points in New England with gale force winds and heavy snow. Blue Hill, Mass., had 13 inches. Pressure fell to 28.50 inches at Nantucket on the 29th.

In January snowfalls were general over New England on the 6–7th, 10th, 16th, and 28–29th. It was a very cold month with little melting; depths accumulated that were adequate for winter sports and for water power.

A late March storm on the 20th dumped 4 to 12 inches along the southeastern coast. The wet snow hit Cape Cod particularly hard with roads blocked and power lines down. Nantucket Island received 11.2 inches.

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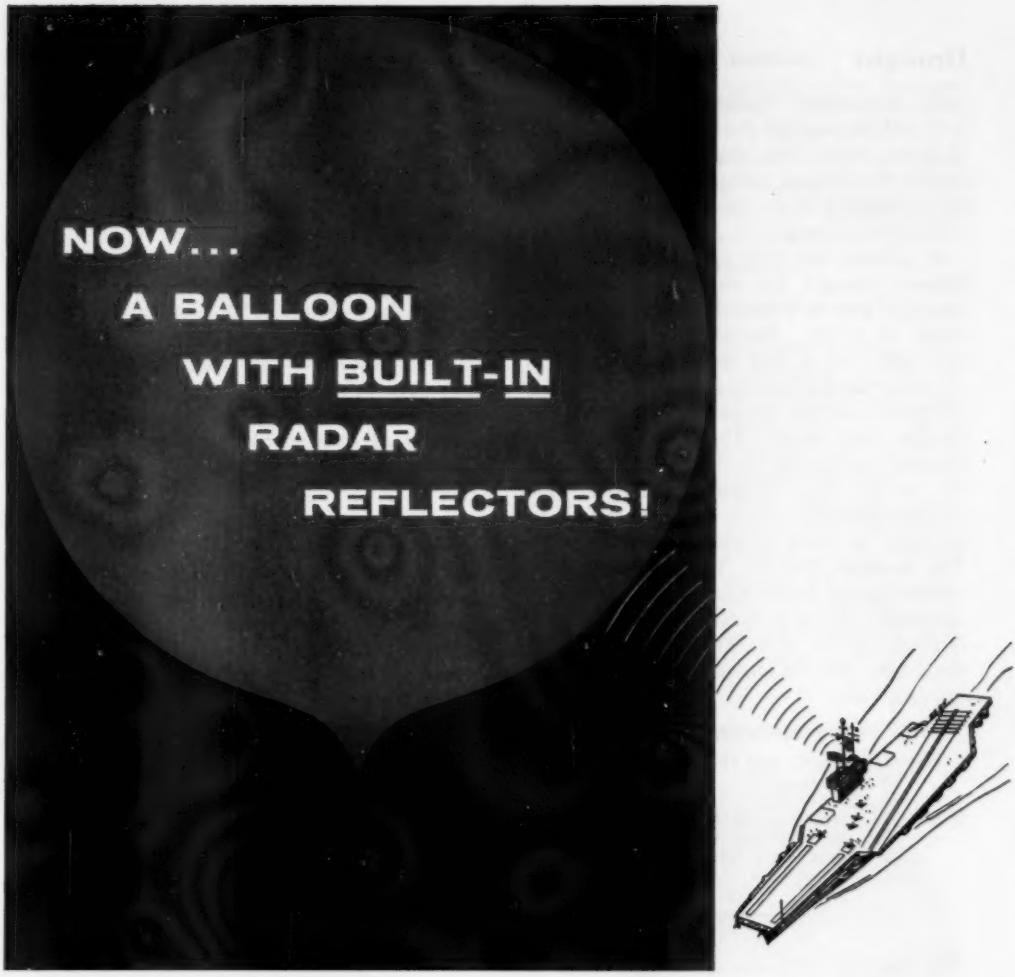

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Drought (*Continued from page 25*)

early September; Bridgeport, mid-September; and Boston and Portland, early October. It is not likely that this is a preferred sequence in this area, but past droughts should be investigated to see whether or not the 1957 pattern was typical.

It appears, but with no certainty, that the Eastern drought has run its course. The question now is where will serious drought strike in 1958? Almost surely some area will suffer for a lack of water. The state of meteorological ignorance precludes the possibility of a reliable forecast of where the 1958 drought will occur. Until continued basic research can provide an adequate understanding of the very complex mechanisms and interrelationships which are responsible for drought, no such prediction can be made. The situation, however, is not without hope; meteorological knowledge has increased tremendously during the past 20 years; and there is every reason to believe that the next 20 years may provide answers to many perplexing problems.

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Hurricane (*Continued from page 19*)

tides and locally heavy rains, with 9.10 inches at Crawfordsville, Fla. Total damages from this storm were small, and there were no fatalities as a direct result of the storm, although it was indirectly responsible for four deaths.

Esther

A weak upper level cyclonic circulation over Central America on the 12th moved northwestward into the southwest Gulf of Mexico on the 15th, where squalliness and abnormally low pressure existed, and resulted in the formation of a tropical depression. The depression grew into tropical storm Esther by late on the 16th and began moving northward about 10 mph. It never developed into an ideal storm with a tight-knit center, but remained with a large central area of relatively light winds roughly 100 miles across. This area moved inland on the southeast Louisiana coast about daybreak on the 18th and continued northward up the Mississippi Valley losing its intensity on the 19th. As in the case of the first storm of the season (unnamed) and Debbie, much of the squalliness and high wind was a considerable distance to the east of the center. The highest reported wind was 52 mph with gusts to 75 mph at Pensacola Airport. The lowest pressure was 1000 mbs (29.53″) reported by reconnaissance aircraft before the storm reached land. Readings of 1003 mbs occurred at New Orleans and McComb, La.

Frieda

Hurricane Frieda, the third hurricane of the current season, spent its life at sea and was of hurricane force only a few hours. On the 20th a cold front pushed southward to the rear of hurricane Carrie and passed the Bermudas, and a low center of 1010 mbs, which appeared at first to be nothing more than an incipient frontal wave, developed rapidly. By early morning of the 21st the LST Narvik reported a central pressure of 1005 mbs in the developing storm about 400 miles south-southwest of Bermuda. Strong low-level easterly winds north of the area, warm sea-surface temperatures, and high-level winds favored intensification. By evening of the 21st, reconnaissance aircraft found central pressure of 1001 mbs and maximum winds of 60 mph in squalls east of the center. Movement was slow towards the southwest at this time.

By morning of the 22nd, shower activity was considerably less than normal and there was no extensive cloud shield, and maximum winds of 50 to 60 mph were encountered by aircraft. A high-level anticyclone northwest of the storm weakened and split in response to the approach of a short wave in the westerlies. The picture at that time was an upper ridge with two cells, one over Florida and the other northeast of Bermuda, which was less favorable for intensification. Little change occurred on the 23rd as it began to move towards the northwest then north at about 10 mph. The storm increased to 20 mph in forward speed towards the north-

northeast on the 24th with little change in surface conditions. On the morning of the 25th the ship Irvingbrook reported a barometer reading of 992 mbs and 80 mph winds. Frieda was now a hurricane, but only a few hours, for a cold front was moving into her circulation. Frieda began under conditions not clearly tropical and became extratropical shortly after reaching hurricane force. Dropsonde reports in the storm indicate slightly warmer than for the mean tropical atmosphere. Throughout the existence of Frieda, the favorable parameters for hurricane formation and maintenance never seemed to be operating concurrently or for long enough time to produce a typical hurricane. After losing her tropical characteristics, the storm continued moving rapidly northeastward, and gradually decreased in intensity and passed over Newfoundland on the night of the 26th.

No deaths have been reported in connection with Frieda, and no property losses charged to her.

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Tornadoes

(*Continued from page 15*)

The tornado damage survey team at Oklahoma State University, Stillwater, Oklahoma, conducted surveys of four tornado situations, plus one wind storm, during 1957 (3). Much data were compiled for future study and some very interesting information regarding wind speeds have already been published. Engineering estimates of wind speeds from structural failure of five different objects showed the wind speed to be at least 135 to 160 mph. One estimate, based upon one tank that overturned and one that did not, placed the wind speed as at least 160, but not as much as

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175 mph. The project engineer, after a survey of the Kansas City tornado, stated that tornado damage could be greatly reduced if builders would employ good construction practices, and follow the specifications set forth by the architects and engineers. Also, it was concluded that much of the damage was caused by pressure reduction.

Much of the tornado damage survey work of the A. & M. College of Texas during 1957 (4), under the supervision of Stuart G. Bigler, was in connection with the aforementioned Dallas tornado. This survey team recorded some 30 very interesting interviews with eye-witnesses which provide considerable detail regarding the nature of the tornado during its life cycle. This tornado overturned several box cars, some of which were loaded with brick and weighed 60 tons. Dependable engineering estimates of wind speeds from these box cars, plus other damaged structures, showed the minimum wind speed to be at least 80–144 mph. Three other estimates, however, gave wind speeds not exceeding 144 mph.

One of the interesting features of tornado research this year is that three different study groups determined wind speeds within the tornado to be around 150 mph. This is, indeed, surprising since most prior estimates or calculations have suggested considerably stronger winds. If these latest determinations are approximately correct, it would seem that the pressure reduction and/or pressure differential is largely responsible for the extensive damage caused by tornadoes. Thus, wind speed in itself may not be as important a factor in property destruction as has been believed in the past.

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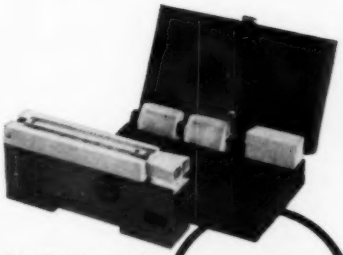

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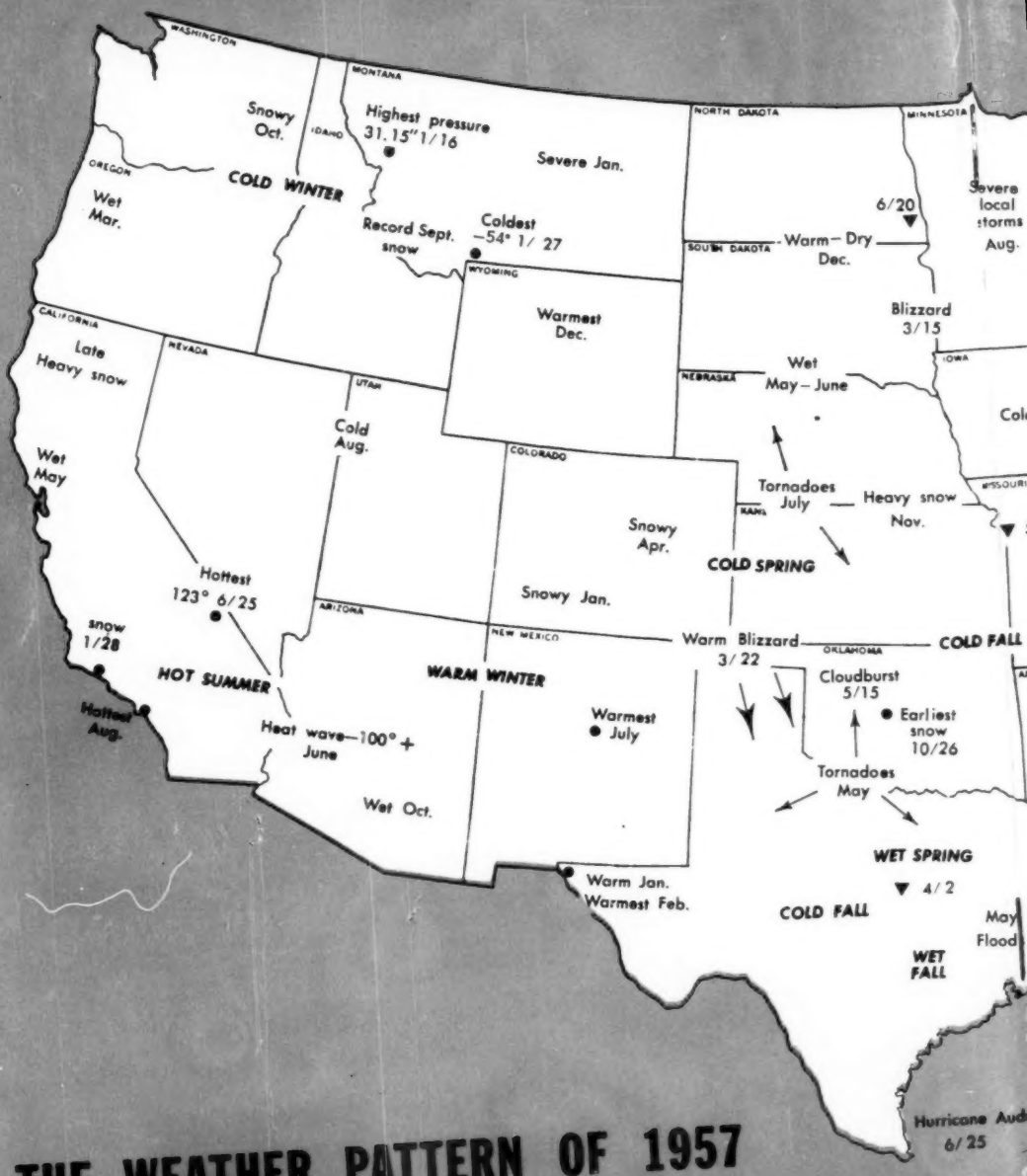

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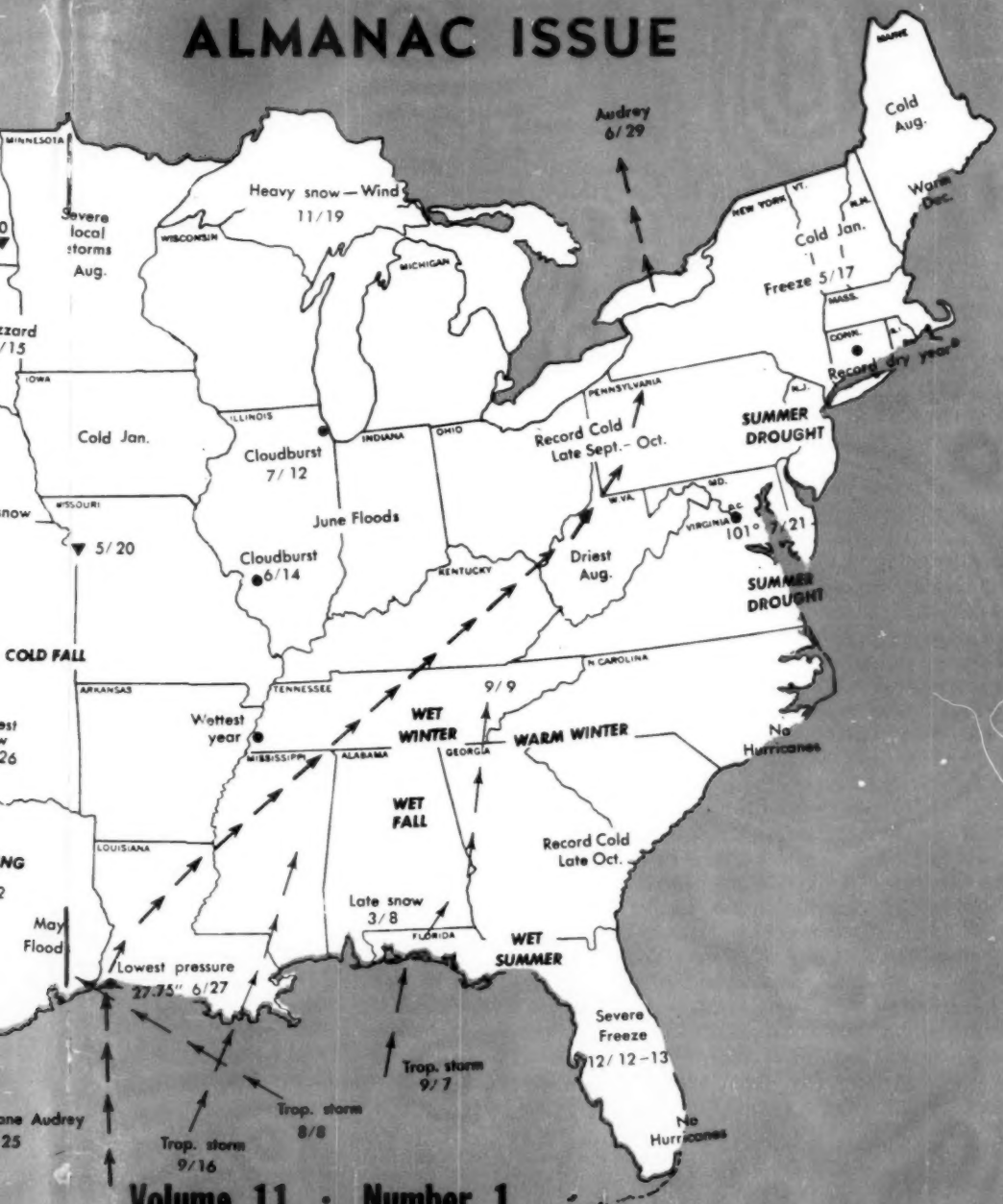

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